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ABSTRACT

This guide contains instructor's materials for a nine-unit secondary school course on fundamentals of electronics. The units are conductors, insulators, semiconductors, and atomic structure; basic concepts and sources of electrical quantities; Ohm's Law; units and conversions; use of multimeters; circuits; electromagnetics and electrostatics; alternating current signals and measurements; and reactive and resonant circuits. The document begins with advice on its use and a cross-referenced table of instructional materials that show which materials in the guide (transparency masters, handouts, assignment sheets, and test items) are directed at which competencies and instructional objectives. Each unit contains the unit objective, student objectives, a list of references, notes to the instructor, lesson plans, a unit test, and answers to the unit test. The lesson plans may include a glossary, information sheets, transparency masters, job sheets, assignment sheets, and test items. (CML)

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70-5002-I
Instructor's Guide

ELECTRONICS
Module

2

FUNDAMENTALS OF ELECTRONICS

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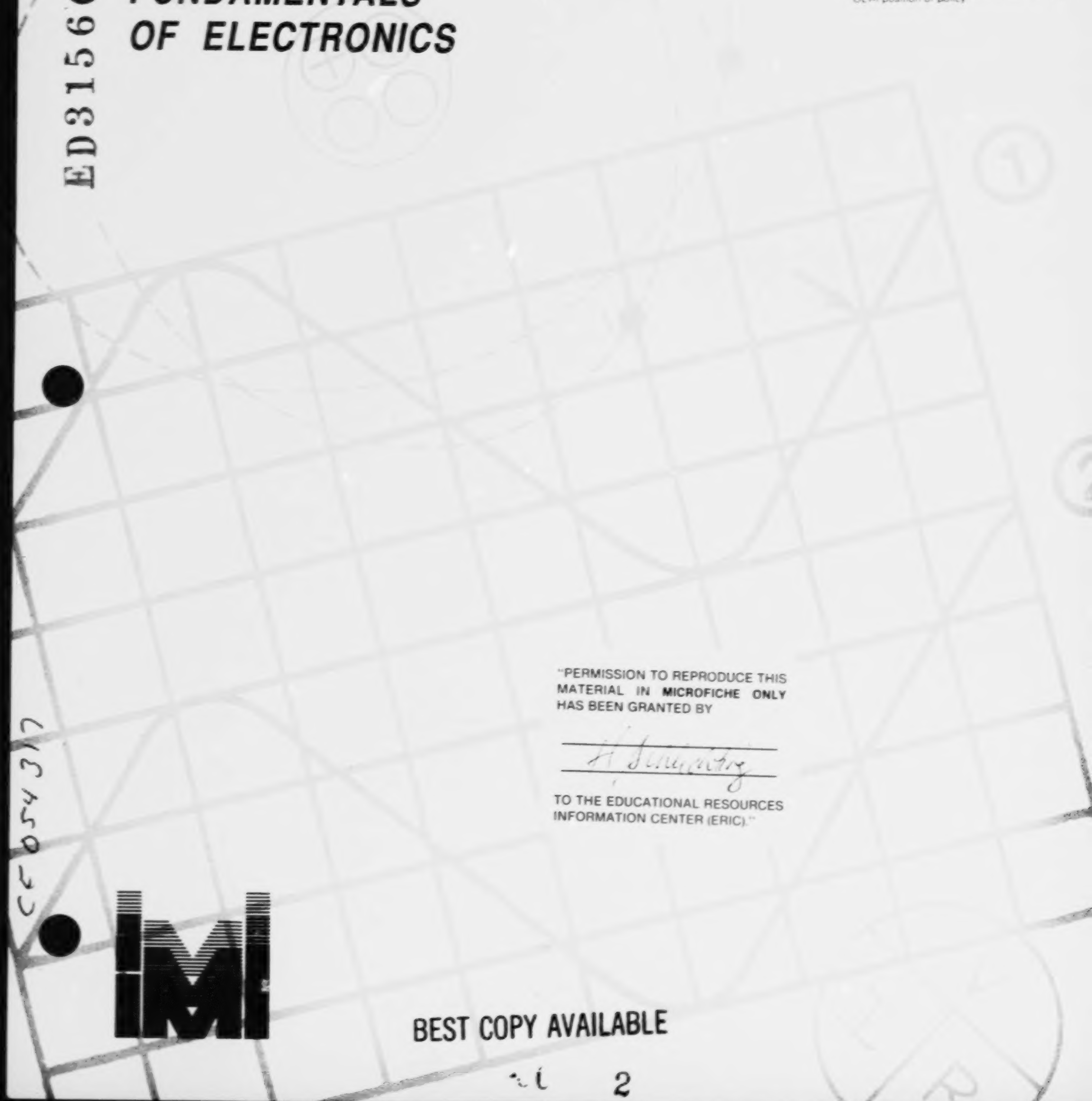

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ELECTRONICS

Module 2: Fundamentals of Electronics

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Instructor's Guide
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FOREWORD

Once again, we are indebted to the teachers and administrators who provide their time, efforts and professionalism to develop curriculum for trade, technical and industrial education programs. This electronics guide is an outstanding example of what can be accomplished when the right people with the right attitude get together. Committee members worked hard over several years' time in advisory, writing, technical consultation and field-test capacities.

This guide is designed to be totally integrated with the Vocational Instructional Management System. It is hoped that all guides produced under our supervision will help classroom teachers manage instruction. A curriculum guide is more than a resource--it is an integral part of the management system. Rather than impeding instruction, it should guide and facilitate instruction.

This guide's format has been set up for competency-based teaching and testing. Unit tests evaluate specific competencies and can be used with the Vocational Administrative Management System (VAMS). Information sheets, transparency masters, job sheets, assignment sheets and test items are keyed to specific competencies. A cross-reference table has been included to quickly identify parts of the curriculum that relate to specific competencies. The material has also been packaged for students.

Although this guide may be a new format for some teachers, we are confident that, when used as designed, time spent by teachers and students will become more productive. Any future electronics curriculum modifications will begin with this guide. The electronics field is undergoing constant and considerable change. We will annually evaluate the need to update this guide on a module-by-module basis. Your suggestions regarding areas for improvement are both encouraged and appreciated.

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Charles "Chuck" Waibel, director
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ACKNOWLEDGMENTS

This electronics guide represents a continuing commitment to Missouri's Vocational Instructional Management System (VIMS). The guide has been keyed to the electronics competency profile developed by industry and education professionals in the state.

When searching for current electronics materials to adopt or utilize in the guide's development, comparable materials were found from the Mid-America Vocational Curriculum Consortium (MAVCC), of which Missouri is a member. MAVCC materials, therefore, have been relied upon as a resource for this guide. A debt of thanks is owed to the entire MAVCC organization for the research and development of these electronics materials.

Special appreciation is given to the writers (Ed Carter, John Chappell, Jim Everett, Bill Franken, Mark Murphy, Don Slack and Bill Tharp) for their self-motivation, reliability and technical expertise. IML employees Crystal Dietiker and Donna Curtis contributed greatly to the guide's production.

These industry representatives and educators contributed to the guide as members of the advisory committee.

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Support and contributions of IML staff members were instrumental to this module's development.

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Phyllis Miller and Dan Stapleton, assistant directors
Crystal Dietiker, graphic artist II
Donna Curtis and Lori Holliday, word processors
Julie Bishop, student assistant - clerical
Wei Li, graduate assistant

TABLE OF CONTENTS

Unit I: Conductors, insulators, semiconductors and atomic structure 1
Unit II: Basic concepts and sources of electrical quantities 33
Unit III: Ohm's law 77
Unit IV: Units and conversions 107
Unit V: Use of multimeters 133
Unit VI: Circuits 175
Unit VII: Electromagnetics and electrostatics 285
Unit VIII: AC signals and measurements 357
Unit IX: Reactive and resonant circuits 401

COMPETENCIES ADDRESSED IN THIS MODULE

B. Fundamentals of Electronics

1. Describe atomic structure and its relationship to electricity
2. Describe the basic physics of semiconductor materials
3. Describe the relationship between electrical and magnetic properties
4. Describe the electrical and magnetic properties of a magnet
5. Describe the photoelectric effect
6. Describe the thermocouple effect
7. Describe the electrical effect of friction
8. Describe the concept of resistance, voltage and current and how they relate to each other
9. Describe the concept of capacitance, voltage and current and how they relate to each other
10. Describe the concept of inductance, voltage and current and how they relate to each other
11. Solve AC network problems utilizing appropriate theorems and laws
12. Identify and test resistors
13. Identify and test capacitors
14. Identify and test inductors
15. Calculate series and parallel; resistive, capacitive and inductive networks
17. Interpret symbols and schematic diagrams
18. Calculate RC time constant circuits
19. Describe and identify filter networks
20. Test and evaluate filter performance

H. Test Equipment

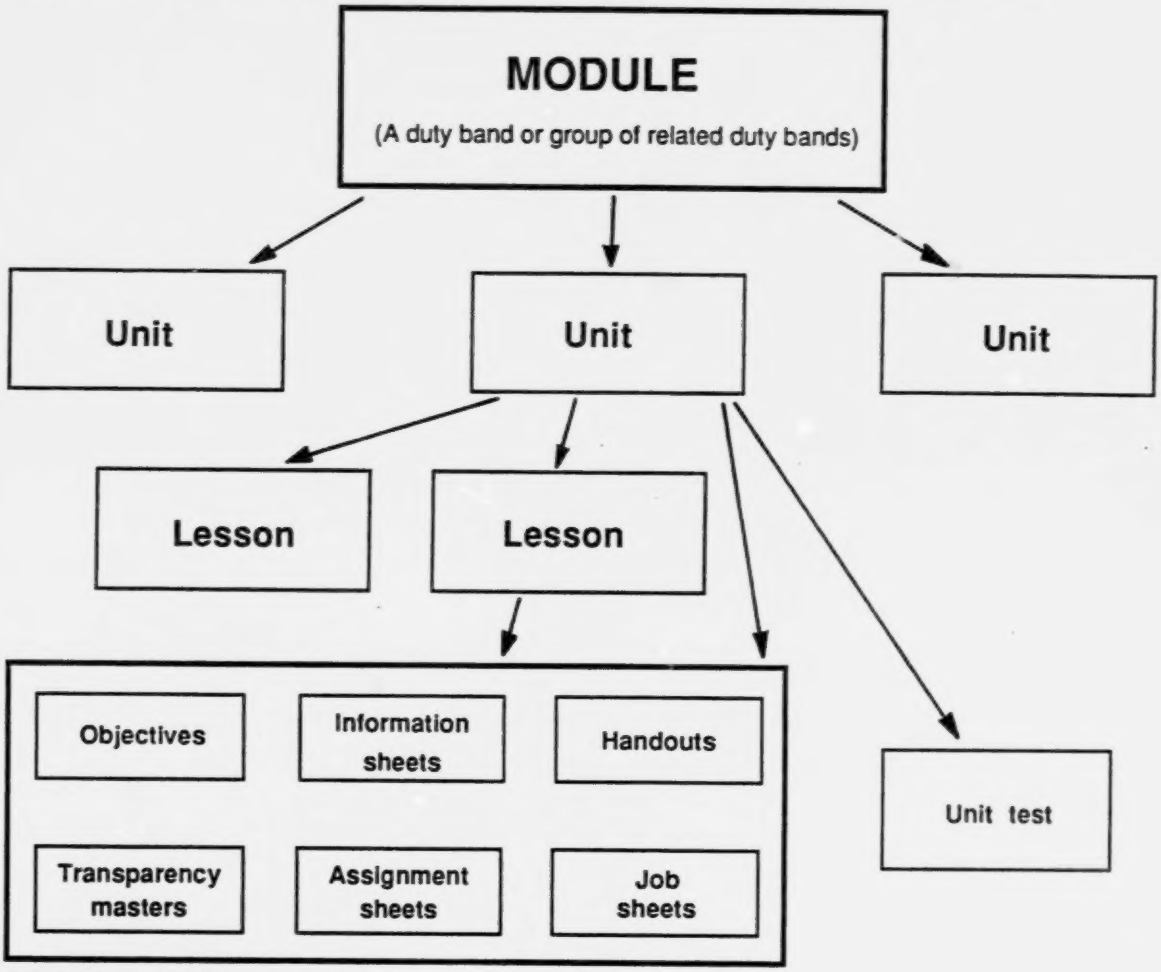
1. Describe the operation and demonstrate the use of an oscilloscope
2. Describe the operation and demonstrate the use of multimeters; i.e., VOM, EVM or DVM
3. Describe the operation and demonstrate the use of signal generators; i.e., audio, RF or function

HOW TO USE THIS PUBLICATION

GUIDE COMPONENTS

Units of instruction

This Electronics guide contains ten modules of instruction. Within each module are instructional units including some or all of the following components: performance objectives, information sheets, transparency masters, handouts, assignment sheets, job sheets and a unit test. Special instructions on audiovisuals, supplies, etc. are included in the Notes to the Instructor section near the beginning of each unit.


MODULE
(A duty band or group of related duty bands)
Unit
Unit
Unit
Lesson
Lesson
Objectives
Information sheets
Handouts
Transparency masters
Assignment sheets
Job sheets
Unit test

Competency profile

On the Missouri competency profile, tasks are divided into general subject areas, or duty bands, which are identified by a capital letter. Under each duty band are related tasks (competencies), which are identified by an Arabic numeral. To evaluate the student on performance of the competencies, a 3-2-1-N grading system is used, where:

3 = **Mastery** - can work independently with no supervision
2 = **Requires supervision** - can perform job completely with limited supervision
1 = **Not mastered** - requires instruction and close supervision
N = **No exposure** - no experience or knowledge in this area

Cross-reference table (color-coded white)

Once the numbering system is understood, this table quickly reveals how the instructional components of the module relate to Missouri competencies. On the competency profile, tasks are divided into general subject areas, or duty bands, which are identified by a capital letter. Under each duty band are related tasks (competencies), which are identified by an Arabic numeral.

On the cross-reference table, unit numbers are represented by Roman numerals (I, II, III, etc.). Lessons within a unit are shown with Arabic numerals. Therefore, the first objective in Lesson 1 is numbered 1.1, the second is 1.2, and so on. Other components of the module (transparencies, handouts, assignment sheets and job sheets) also use this numbering system. By looking at the cross-reference table, the instructor can quickly determine what test questions or job sheets a student needs to receive an evaluation on a particular competency.

Objectives (color-coded white)

Each unit is based on performance objectives which state the measurable unit and specific behavioral or performance objectives that students are expected to achieve. Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the objectives' intent. Teachers should feel free to add/adapt objectives which will fit the material to student and community needs. Supporting material will, of course, need to be added for any new objectives.

Table of contents, references, notes to the instructor (color-coded pink)

These pages have been coded pink for instructor use only. The reference section lists materials used as sources in developing the material. Special instructions on audiovisuals, supplies, etc. are included in the Notes to the Instructor section.

Information sheets (green)

Presented in outline form for clarity, these pages provide content essential for meeting the cognitive (knowledge) objectives in the unit. Students should study the information sheets before class discussion or completion of assignment sheets. **CAUTION** statements indicate possible equipment damage, while **WARNING** statements recommend procedures to avoid bodily injury. Handouts and transparency masters have been keyed in the information sheets for instructional use.

Transparency masters (white)

Transparencies provide information by visually reinforcing or clarifying ideas presented in the information sheets. They are effective when identification is necessary and direct the class's attention to the topic of discussion. Transparencies should be left on the screen only when topics shown are under discussion, however.

Handouts (white)

Whenever more detailed information than can be presented in a transparency is needed, a handout is used. Handouts give the students additional information that can be kept with their class notes or student references.

Assignment sheets (tan)

Assignment sheets furnish paper-and-pencil practice to develop the knowledge necessary as a prerequisite to skill development. They can be given to students for class completion or used as homework assignments. Answer sheets (color-coded pink) can be used by the student or instructor to check progress.

Job sheets (blue)

These evaluation instruments are provided for two purposes: to outline steps of procedure and to check student performance mastery. Job sheets begin with a list of tools and materials needed for the activity. Job sheets furnish potential employers with a picture of skills being taught and performance which might be reasonably expected from a vocational student. The spaces to the right of the page on a job sheet assist the instructor in evaluating a student on a particular activity. This 3-2-1-N grading system is the same as the one used on the competency profile.

Unit test (yellow)

Competency-based tests are designed to help eliminate subjective testing and to improve student evaluation and accountability. Specific competencies and test questions are linked on the answer key. These welding unit tests have been written to be used with computerized VAMS (Vocational Administrative Management System), utilizing Scantron sheets for computer-recording of test answers.

The unit test may be eliminated if the competency was thoroughly evaluated by job sheets. However, an emphasis should be placed on cognitive as well as performance skills. If the objective or competency will be evaluated by a job sheet, it is often necessary to determine by a written test whether the student understands enough of the material to perform the job sheet.

SUGGESTED ACTIVITIES

The following list of suggested activities may be helpful, especially to the beginning instructor.

1. Provide students with objective sheet and information sheets.
2. Discuss unit and specific objectives.
3. Discuss information sheets, assignment sheets and/or job sheets, lesson-by-lesson.
4. Have students do assignment sheet(s) to satisfactory levels.
5. Give students unit test.
6. After successful completion of the test, have students do job sheet(s).

Students should perform the following activities.

1. Read objective sheet.
2. Study information sheets.
3. Do assignment sheet(s).
4. Take unit test.
5. Do job sheets.

PACKAGING

This Electronics guide has been packaged with the entire class in mind. For the teacher, a complete instructor's guide contains all ten modules. In the student reference, selected portions have been reproduced for student use (objectives page, information sheets, handouts). Student work sheets (assignment sheets, job sheets, unit tests) have been packaged together for student distribution as the instructor deems necessary.

In the student reference, page numbers do not run consecutively because some pages have been removed that appear only in the instructor's guide.

MODULE 2: FUNDAMENTALS OF ELECTRONICS

CROSS-REFERENCE TABLE OF INSTRUCTIONAL MATERIALS

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
B1	I 1.1-1.4,3.1		I 3.1	I 1.1		I 1-10	
B2	I 2.1,2.2,3.2,3.3	I 2.1	I 3.2	I 3.1		I 11-19	
B3	VII 1.1,1.3	VII 1.3-1.5	VII 1.2-1.4	VII 1.1		VII 4-10	
B4	VII 1.2	VII 1.1,1.2	VII 1.1			VII 1-3	
B5	II 1.1			II 1.1		II 9	Also in Optical module
B6	II 1.1,1.2			II 1.1		II 1	
B7	II 4.1-4.3			II 4.1		II 31-33,36	
B8	II 2.1,2.2,3.1, 3.2,5.1,5.2,6.1,6.2, III 1.1,2.1			II 4.1,5.1,6.1, III 1.1-1.3, 2.1-2.4		II 4,5,11-30, 34,35,37-46, III 1-15	
B9	VII 2.1,2.2					VII 16-25, IX 12-20,27	
B10	VII 1.4, IX 1.1,1.2	VII 1.6-1.8		VII 1.2		VII 11-13, IX 1-8	
B11	VIII 1.1-1.5,2.2, IX 1.3,1.4,2.2		VIII 1.1	VIII 1.1,2.2, IX 1.1,1.2	VIII 1.1,2.1, IX 1.1-1.5	VIII 1-10, 16-22,24	
B12	V 2.1-2.3,2.8, VI 1.1-1.4	V 2.1-2.5	VI 1.1	V 2.1,2.2, VI 1.1	V 2.1-2.3	V 1-13, VI 1-6	
B13	VII 2.3, 2.4,2.6				VII 2.1		

MODULE 2: FUNDAMENTALS OF ELECTRONICS (Cont.)

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
B14	VII 1.5		VII 1.5	VII 1.2		VII 14-15	
B15	VI 2.1,2.3,3.1-3.5, 4.1,5.1,5.2,6.1-6.3	VI 2.1,2.2,3.1, 5.1,5.2,6.1	VI 3.1,3.2, 4.1-4.3	VI 2.1-2.6,3.1-3.4,4.1-4.4,5.1	VI 2.1,2.2,3.1 3.2,4.1,4.2, 5.1,6.1	VI 7-32	Prerequisite: Unit IV
B16							Circuit Construction, Unit I
B17	IV 1.2					IV 5-7, IX 9-11	Also in Circuit Construction, Unit I
B18	VII 2.5,2.7	VII 2.1,2.2	VII 2.1	VII 1.2,2.1,2.2	VII 2.2,2.3		
B19	IX 2.1,2.3	IX 2.1,2.2	IX 2.1,2.2			IX 21-26,28-33	
B20	IX 2.4			IX 2.1,2.2	IX 2.1,2.2		
H1	VIII 2.1,2.3-2.5	VIII 2.1,2.2	VIII 2.1,2.2	VIII 2.1	VIII 2.2	VIII 11-15, 23,25-27	
H2	V 1.1-1.3,2.4-2.8			V 1.1	V 2.1-2.3		
H3	VIII 2.5				VIII 2.2		

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT I: CONDUCTORS, INSULATORS, SEMICONDUCTORS AND ATOMIC STRUCTURE

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to identify parts of basic atomic structure. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student will be able to:

1.1 Define aspects of atomic structure and characteristics. (competency B1)

1.2 Identify and locate the basic parts of an atom. (competency B1)

1.3 Explain how atoms are grouped. (competency B1)

1.4 Explain the affect on particles of like and unlike polarity. (competency B1)

2.1 Define terms related to conductor and insulator characteristics. (competency B2)

2.2 Identify characteristics of conductors and insulators. (competency B2)

3.1 Describe the types of bonding between atoms. (competency B1)

3.2 Identify the basic characteristics of semiconductors. (competency B2)

3.3 Locate basic information on a Periodic Table of the Elements. (competency B2)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT I: CONDUCTORS, INSULATORS, SEMICONDUCTORS AND ATOMIC STRUCTURE

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: ATOMIC STRUCTURE AND CHARACTERISTICS
    - a. Information outline
    - b. Assignment sheet
        - AS 1.1: Atomic structure
    - c. Answers to assignment sheet
2. Lesson 2: CHARACTERISTICS OF CONDUCTORS AND INSULATORS
    - a. Information outline
    - b. Transparency
        - TM 2.1: Resistance of conductors and insulators
3. Lesson 3: SEMICONDUCTORS
    - a. Information outline
    - b. Handouts
        - HO 3.1: Atomic model
        - HO 3.2: Periodic Table of the Elements
    - c. Assignment sheet
        - AS 3.1: Semiconductors
    - d. Answers to assignment sheet

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.

2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

3. Graf, Rudolf F. Modern Dictionary of Electronics. Indianapolis, IN: Howard W. Sams & Co., Inc., 1984.

4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

5. Schuler, Charles A.; Richard J. Fowler. Basic Electricity and Electronics. St. Louis: McGraw-Hill, 1988.

B. Curriculum guides

1. Hartman, Lonnie. Basic Electronics. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

2. Robertson, L. Paul. Basic Electronics I. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1980.

3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Information on elements and compounds from chemistry teachers can provide additional handouts or transparencies.

2. A brief introduction to the Periodic Table of the Elements is useful. Point out that 1) metals are clustered together; 2) noble gasses used in "neon" signs are all in one column (mixtures make the various colors); and 3) that base semiconductor materials are all in one column, N-type doping materials are in the next column and P-type are in the column on the other side.

B. Suggested supplemental materials

1. "Concepts of Electricity" (EVV-3100-1). Heath Company.

   NOTE: The above videotape covers basic atomic structure but not semiconductors.

2. Bruce, David. Modern Electronic Basics, Devices and Applications. Reston, Va.: Reston Publishing Co., Inc., Prentice-Hall, 1984.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT I: CONDUCTORS, INSULATORS, SEMICONDUCTORS AND ATOMIC STRUCTURE

LESSON 1: ATOMIC STRUCTURE AND CHARACTERISTICS

NOTE: Everything (including electronic circuits) is composed of atoms. These information sheets will explain why materials exhibit certain characteristics. A technician needs to predict the effect of his/her actions when installing or repairing electronic components.

I. Terms and definitions

A. Atom--smallest unit of matter that retains characteristics of an element

B. Carrier--the particle of an electric current

C. Charge--a quantity of electricity measured in Coulombs

D. Compound--result of atoms of different elements joining chemically

E. Electron--lightest of the three basic particles of an atom. It is negatively charged and orbits the nucleus of the atom. Electronics and electricity study the control of electrons and their movement.

F. Element--matter composed entirely of identical atoms. Elements are described on the Periodic Table of Elements.

G. Free electrons--electrons that can move freely from one location to another, usually found in a conductor. These electrons are in the valence shell of the atom.

H. Ion--an atom with an unbalanced number of electrons compared to the number of protons in the nucleus (see positive and negative ions)

I. Ionic--bond between differently charged ions due to the attraction between opposite charges

J. Negative ion (anion)--atom with more electrons than protons, creating a net negative charge for the whole atom

K. Mixture--result of placing two different types of material together when it does not join chemically

L. Molecule--smallest unit of a substance (e.g. water). Dividing a molecule results in something with different characteristics (e.g. oxygen and hydrogen).

M. Neutron--part of the nucleus of an atom. Unlike the electron (-) and proton (+), the neutron has no polarity.

N. Nucleus--center of the atom composed of the protons and neutrons. It is the most dense part of the atom.

O. Positive ion (cation)--atom with fewer electrons than protons, creating a net positive charge for the whole atom

P. Proton--positively charged part of an atom's nucleus. The number of protons in the nucleus determines what the element is.

Q. Valence shell--outermost shell of an atom containing the electrons. The valence shell determines whether the material is a conductor, semi-conductor or insulator.

II. Atomic structure

A. Nucleus

1. Neutrons

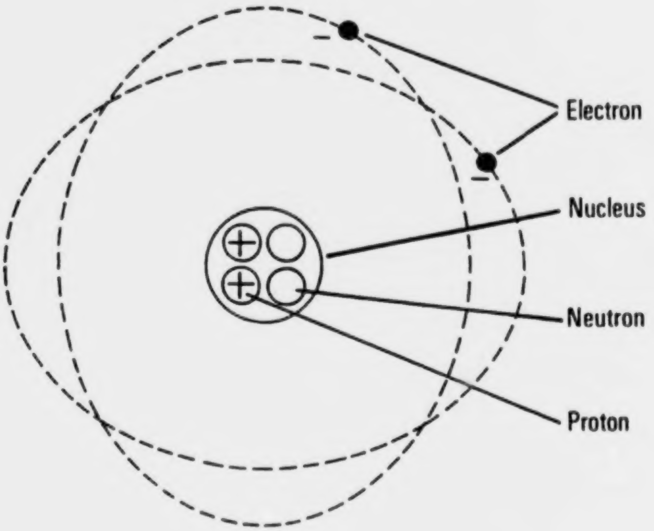
2. Protons

B. Orbitals

1. Electrons

2. Electrons in various shells

3. Outer shell is the valence shell



III. Groups of atoms

A. Elements

1. All atoms of one element have the same number of protons.

2. Elements are identified on the Periodic Table of Elements.

B. Compounds

1. Compounds are composed of atoms of different elements that are joined chemically.

2. The smallest unit of a compound is a molecule.

3. A compound's characteristics are usually different than the characteristics of the individual elements from which it is made.

C. Mixtures

1. Mixtures are composed of atoms or molecules that are assembled physically but not chemically.

2. A mixture's ingredients maintain their individual characteristics.

IV. Characteristics of charged particles

A. Like charges (positive-to-positive or negative-to-negative) repel.

1. Two protons or positive ions will repel each other.

2. Two electrons or negative ions will repel each other.

B. Unlike charges (positive-to-negative) attract.

1. Protons and electrons attract.
2. Positive ions and electrons attract.
3. Negative ions and protons attract.

ATOMIC STRUCTURE

Fill in the blanks with the proper word or words.

1. The nucleus of an atom contains two parts, the _______ and the _______ .
2. An atom's basic part in the orbitals around the nucleus is the _______ .
3. The outermost shell of the atom is called the _________ shell.
4. The Periodic Table provides information on the _________ .
5. Atoms joined chemically are called _________ .
6. Like charges _________ and unlike charges _________ .
7. The two types of ions are _________ and _________ .

ANSWERS TO AS 1.1

1. Proton, neutron
2. Electron
3. Valence
4. Elements
5. Compounds
6. Repel, attract
7. Positive, negative

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT I: CONDUCTORS, INSULATORS, SEMICONDUCTORS AND ATOMIC STRUCTURE

LESSON 2: CHARACTERISTICS OF CONDUCTORS AND INSULATORS

NOTE: Circuit boards, extension cords, volume controls and most parts in electronic devices can be divided into two categories: conductors and insulators. Knowing their basic characteristics is necessary for a competent technician.

I. Terms and definitions

  A. Co-valent--bond between two atoms forming an electron pair. This bonding is used in the structure of semiconductors.

  B. Conductor--material that has little resistance to the flow of electrons. Usually made of single elements such as copper, aluminum, silver, gold, etc.

  C. Doping--addition of controlled amounts of impurities to create N-type or P-type semiconductor material

  D. Extrinsic--semiconductor that has been made impure by doping. N-type and P-type semiconductors are extrinsic.

  E. Hole--imaginary positive charge that explains the gap in co-valent bonds of P-type semiconductors

  F. Insulator--material that has a high degree of resistance to the flow of electrons. Usually made of compounds such as certain types of glass, rubber or plastic.

  G. Intrinsic--semiconductor material that is chemically pure, without doping impurities; in this state, semiconductor material is an insulator.

  H. Majority carrier--the dominant type of carrier. For N-type material, electrons are majority carriers. For P-type material, holes are majority carriers.

  I. Minority carrier--the minority carrier type. For N-type material, holes are minority carriers. For P-type material, electrons are minority carriers.

  J. Negative ion (anion)--atom with more electrons than protons, creating a net negative charge for the whole atom

II. Conductors vs. insulators (TM 2.1)

  A. Conductors

    1. Conductors have little resistance to the flow of electrons

    2. Common characteristics

      a. Usually made of metals

      b. Usually made of a single element such as copper or silver

    3. Valence shell electrons are not tightly attracted to the nucleus.

B. Insulators

1. Insulators have greater resistance to the flow of electrons.
2. Common characteristics
   a. Usually made of non-metals
   b. Usually made of compounds such as glass, rubber or plastic
3. Valence shell electrons are very tightly attracted to the nucleus.

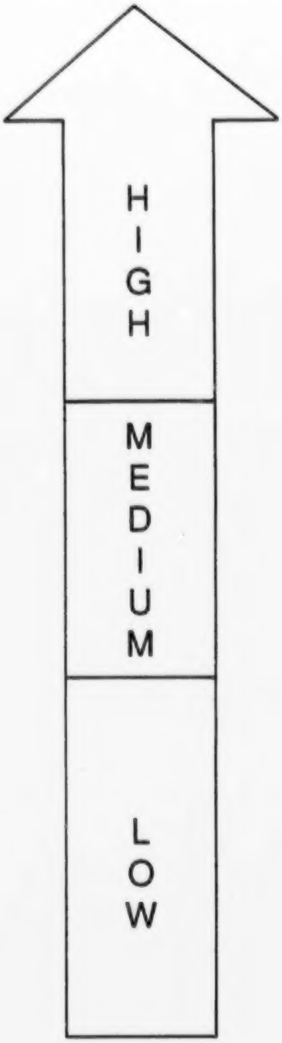
RESISTANCE OF CONDUCTORS AND INSULATORS

Insulators
- Air or vacuum
- Fiber
- Bakelite®
- Rubber
- Paper
- Shellac
- Glass
- Mica
- Ceramics

Semiconductors
- Germanium
- Silicon

Conductors
- Silver
- Copper
- Gold
- Aluminum
- Tungsten
- Nickel
- Iron

Increasing Resistance



MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT I: CONDUCTORS, INSULATORS, SEMICONDUCTORS AND ATOMIC STRUCTURE

LESSON 3: SEMICONDUCTORS

NOTE: Semiconductors are used in almost every sophisticated electronic device--from thermostats to computers. Information about semiconductors will help knowledgeable technicians troubleshoot and repair these devices.

I. Bonding

   A. Co-valent

      1. Insulators

      2. Semi-conductors

   B. Ionic (gases)

II. Semiconductor crystal type structures and characteristics (HO 3.1)

   A. Intrinsic

   B. Extrinsic

      1. N-type, electrons

      2. P-type, holes

   C. Majority carriers

      1. Electrons in N-type material

      2. Holes in P-type material

   D. Minority carriers

      1. Holes in N-type material

      2. Electrons in P-type material

   E. Affects of temperature

      1. Affect of temperature on semiconductor resistance

      2. Thermal runaway

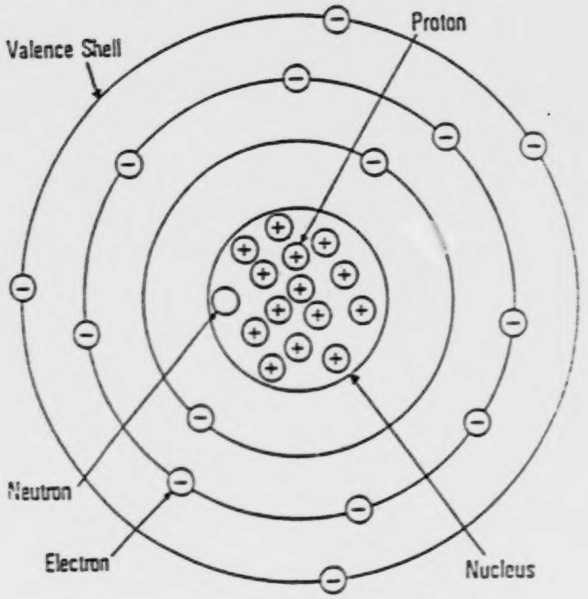
IV. Basic information on the Periodic Table (HO 3.2)

- A. Location of valence shell information
- B. Noble gas locations
- C. Semiconductor locations
- D. Doping material locations

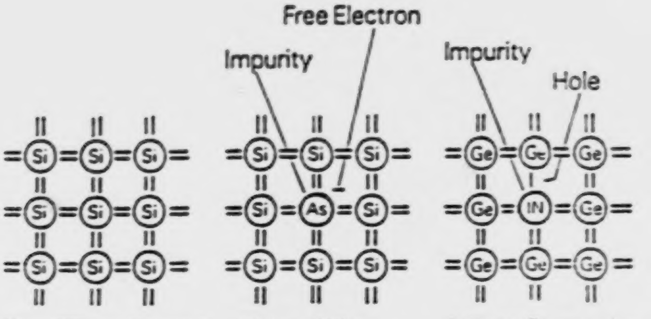
HO 3.1

ATOMIC MODEL

(Silicon)


Valence Shell
Proton
Neutron
Electron
Nucleus

Semiconductor Crystal Structures


Free Electron
Impurity
Impurity
Hole
Si
As
Ge
IN

Pure Silicon Crystal
Intrinsic

N-Type Silicon
Crystal
Extrinsic

P-Type Germanium
Crystal
Extrinsic

PERIODIC TABLE OF THE ELEMENTS

In the periodic table the elements are arranged in order of increasing atomic number. Vertical columns headed by Roman numerals are called *Groups*. A horizontal sequence of elements is called a *Period*. The most active elements are at the top right and bottom left of the table. The staggered line (Groups IIIA-VIIA) roughly separates metallic from non-metallic elements.

Groups—Elements within a group have similar properties and contain the same number of electrons in their outside energy shell.

—The first group (IA) includes hydrogen and the alkali metals.

—The last (VIIIA) contains the *inert gases*.

—Group VIIA includes the *halogens*.

—The elements intervening between groups IIA and IIIA are called *transition elements*.

—Short vertical columns without Roman numeral headings are called sub-groups.

Periods—In a given period the properties of the elements gradually pass from a strong metallic to a strong non-metallic nature, with the last number of a period being an inert gas.

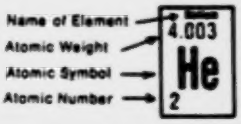
LIGHT METALS: IA, IIA

NON METALS: IIIA, IVA, VA, VIA, VIIA

IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
1.0080 H 1																	4.003 He 2
6.939 Li 3	9.012 Be 4											10.811 B 5	12.01115 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.183 Ne 10
22.990 Na 11	24.312 Mg 12											26.981 Al 13	28.086 Si 14	30.974 P 15	32.064 S 16	35.453 Cl 17	39.948 Ar 18
39.102 K 19	40.08 Ca 20	44.956 Sc 21	47.90 Ti 22	50.942 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.71 Ni 28	63.54 Cu 29	65.37 Zn 30	69.72 Ga 31	72.59 Ge 32	74.922 As 33	78.96 Se 34	79.909 Br 35	83.80 Kr 36
85.47 Rb 37	87.62 Sr 38	88.905 Y 39	91.22 Zr 40	92.906 Nb 41	95.94 Mo 42	(99) Tc 43	101.07 Ru 44	102.91 Rh 45	106.4 Pd 46	107.87 Ag 47	112.40 Cd 48	114.82 In 49	118.69 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.30 Xe 54
132.90 Cs 55	137.34 Ba 56	57-71	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.2 Os 76	192.2 Ir 77	195.09 Pt 78	196.97 Au 79	200.59 Hg 80	204.37 Tl 81	207.19 Pb 82	208.98 Bi 83	(210) Po 84	(210) At 85	(222) Rn 86
223 Fr 87	(226) Ra 88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118

138.91 La 57	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(147) Pm 61	150.35 Sm 62	151.96 Eu 63	157.25 Gd 64	158.92 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	174.97 Lu 71
227 Ac 89	232.04 Th 90	(231) Pa 91	238.03 U 92	(237) Np 93	(242) Pu 94	(243) Am 95	(247) Cm 96	(249) Bk 97	(251) Cf 98	(254) Es 99	(253) Fm 100	(256) Md 101	(254) No 102	(257) Lr 103

Key



Credit: "Chemistry handout." (RAD 211-5324) U.S. Navy, n.d.

SEMICONDUCTORS

Fill in the blanks with the proper word or words.

1. Semiconductors use _________ bonding.
2. Ionic bonding is the result of the attraction of _________ charges.
3. Pure semiconductor material is called _________ .
4. When a semiconductor material is doped it is called _________ .
5. N-type semiconductor material contains excess _________ outside the co-valent bonds.
6. P-type semiconductor material contains _________ inside the co-valent bonds.
7. Majority carriers in N-type material are _________ .
8. ·Majority carriers in P-type materials are _________ .
9. Increased temperature in a semiconductor material causes a(n) _________ in its resistance.
10. A semiconductor circuit getting too hot can cause _________ .
11. If valence electrons are loosely held, the material is a(n) _________ .
12. If valence electrons are tightly held, the material is a(n) _________ .
13. While conductors are usually elements, insulators are usually _________ .

ANSWERS TO AS 3.1

1. Co-valent
2. Unlike
3. Intrinsic
4. Extrinsic
5. Electrons
6. Holes
7. Electrons
8. Holes
9. Decrease
10. Thermal runaway
11. Conductor
12. Insulator
13. Compounds

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT I: CONDUCTORS, INSULATORS, SEMICONDUCTORS AND ATOMIC STRUCTURE

UNIT TEST

Choose the option which best answers the question or completes the statement.

____ 1. What does the nucleus of the atom contain?

a. Electrons
b. Protons
c. Ions
d. Valance
e. All of the above

____ 2. Which part of the atom has neither a negative nor positive charge?

a. Neutron
b. Positron
c. Element
d. Electron
e. Ion

____ 3. Which describes the valence shell?

a. The closest to the nucleus
b. Furthest from the nucleus
c. In the nucleus
d. An empty shell
e. None of the above

____ 4. Which of the following describes electrons?

a. They have a neutral charge.
b. They are in the nucleus with the nucleons.
c. They have a positive charge.
d. They are in orbitals around the nucleus.
e. None of the above

____ 5. A proton __________ .

a. Would repel a positive ion
b. Is in the orbitals around the nucleus
c. Would repel an electron
d. Has a negative charge
e. Repels a negative ion

____ 6. Which of the following does a positive ion have?

a. More electrons than protons
b. More positrons than electrons
c. Fewer electrons than protons
d. More neutrons than protons
e. None of the above

____ 7. Electrons in the valence shell are ________ .

a. Attracted by the neutrons
b. Attracted by the protons
c. Repelled by the neutrons
d. Repelled by the protons
e. Attracted by both protons and neutrons

____ 8. Which does a negative ion have?

a. More electrons than protons
b. Fewer electrons than protons
c. More positrons than electrons
d. More neutrons than protons
e. More neutrons and electrons than protons

____ 9. A negative ion will repel which of the following?

a. Nucleus
b. Positive ion
c. Proton
d. Electron
e. None of the above

____ 10. A compound is made up of elements and has characteristics ________ .

a. Identified closely with its elements
b. Different than its elements
c. That cannot be identified
d. That are like one of the elements, but not the other
e. The same as its elements

____ 11. Co-valent bonding is used with which of the following?

a. Solids
b. Conductors
c. Liquids
d. Semiconductors
e. Gases

____ 12. What is pure crystalline material, without doping, called?

a. Intrinsic
b. Extrinsic
c. Ionic
d. Antidoped
e. Doped

____ 13. N-type semiconductor material has __________ .

a. Negative bias due to the lack of electrons in the valence shell
b. More electrons than fit into the co-valent bonds
c. Electrons in the nucleus
d. Protons in the valence shell
e. More protons than fit into the co-valent bonds

____ 14. What are metals usually associated with?

a. Insulators
b. Conductors
c. Semiconductors
d. Co-valent bonding
e. None of the above

____ 15. Temperature __________ .

a. Will not affect the semiconductor
b. Affects the efficiency of semiconductors
c. Affects the resistance of semiconductors
d. Both b and c
e. None of the above

____ 16. Compounds are used as __________ .

a. Insulators
b. Conductors
c. Semiconductors
d. Co-valent bonds
e. All of the above

____ 17. The valence shell of a semiconductor atom has __________ .

a. Four electrons
b. Eight electrons
c. Full valence shells
d. Both b and c
e. None of the above

____ 18. Intrinsic semiconductor material __________ .

a. Is more of a conductor than extrinsic material
b. Cannot be manufactured
c. Is always N-type material
d. Is more of an insulator than extrinsic material
e. Is always P-type material

____ 19. Co-valent bonding __________ .

a. Is the basis of making semi-conductor material
b. Is the same as ionic bonding
c. Is a weak, non-permanent form of laboratory bonding
d. Both b and c
e. None of the above

Match the following terms and definitions.

____ 20. Atom with more electrons than protons, creating a net negative charge for the whole atom

____ 21. Bond between differently charged ions due to the attraction between opposite charges

____ 22. Bond between two atoms forming an electron pair. This bonding is used in the structure of semiconductors.

____ 23. Imaginary positive charge that explains the gap in co-valent bonds of P-type semiconductors

____ 24. Material that has little resistance to the flow of electrons.

____ 25. Outermost shell of an atom containing the electrons

____ 26. Part of the nucleus of an atom that has no polarity

____ 27. Positively charged part of an atom's nucleus; determines what the element is

____ 28. Result of placing two different types of material together when it does not join chemically

____ 29. Semiconductor that has been made impure by doping

____ 30. Smallest unit of a substance (e.g. water)

____ 31. Smallest unit of matter that retains characteristics of an element

____ 32. The dominant type of carrier

____ 33. The particle of an electric current

a. Atom

b. Carrier

c. Co-valent

d. Conductor

e. Extrinsic

ab. Hole

ac. Ionic

ad. Majority carrier

ae. Mixture

bc. Molecule

bd. Negative ion (anion)

be. Neutron

cd. Proton

ce. Valence shell

ANSWERS TO UNIT TEST

1.	b	(B1)
2.	a	(B1)
3.	b	(B1)
4.	d	(B1)
5.	a	(B1)
6.	c	(B1)
7.	b	(B1)
8.	a	(B1)
9.	d	(B1)
10.	b	(B1)
11.	d	(B2)
12.	a	(B2)
13.	b	(B2)
14.	b	(B2)
15.	d	(B2)
16.	a	(B2)
17.	a	(B2)
18.	d	(B2)
19.	a	(B2)
20.	bd	
21.	ac	
22.	c	
23.	ab	
24.	d	
25.	ce	
26.	be	
27.	cd	
28.	ae	
29.	e	
30.	bc	
31.	a	
32.	ad	
33.	b	

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to describe and/or define I (current), V (voltage), R (resistance), P (power) and the sources of each. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student will be able to:

1.1 Define terms used when describing power sources. (competency B5, B6)

1.2 Identify power source safety considerations. (competency B6)

2.1 Define terms used when describing current. (competency B8)

2.2 Identify commonly used symbols for current, charge and their units. (competency B8)

3.1 Define voltage and its unit. (competency B8)

3.2 Explain the concept of voltage. (competency B8)

4.1 Define resistance terms. (competency B7)

4.2 Identify commonly used symbols for resistance and its unit. (competency B7)

4.3 Describe physical characteristics affecting resistance. (competency B7)

5.1 Define terms related to power. (competency B8)

5.2 Identify quantities, symbols and concepts of power. (competency B8)

6.1 Identify directly and inversely proportional relationships. (competency B8)

6.2 Identify schematic symbols for cell, battery and resistor. (competency B8)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to instructor

D. Lesson plans

1. Lesson 1: POWER SOURCES
   a. Information outline
   b. Assignment sheet
      AS 1.1: Power sources
   c. Answers to assignment sheet
2. Lesson 2: CURRENT
   a. Information outline
3. Lesson 3: VOLTAGE
   a. Information outline
4. Lesson 4: RESISTANCE
   a. Information outline
   b. Assignment sheet
      AS 4.1: Current, voltage and resistance
   c. Answers to assignment sheet
5. Lesson 5: POWER
   a. Information outline
   b. Assignment sheet
      AS 5.1: Power
   c. Answers to assignment sheet
6. Lesson 6: PROPORTIONALITY AND SCHEMATIC SYMBOLS
   a. Information outline

  - b. Assignment sheet

    AS 6.1: Relationship of voltage, current, resistance and power

  - c. Answers to assignment sheet

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.

2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

3. Graf, Rudolf F. Modern Dictionary of Electronics. 6th ed. Indianapolis, IN: Howard W. Sams & Co., Inc., 1984.

4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

5. Schuler, Charles A.; Richard J. Fowler. Basic Electricity and Electronics. St. Louis: McGraw-Hill, 1988.

B. Curriculum guides

1. Hartman, Lonnie. Basic Electronics. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

2. Robertson, L. Paul. Basic Electronics I. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1980.

3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. This introduction to common electrical power sources, current, voltage, resistance, power and how they relate is intended to provide the student with initial concepts.

2. This information is an introduction to the physical laws of force (voltage), rate (current), resistance and rate of energy use (power). Using models of water are useful. However, ask students to offer their own ideas of how other systems (mechanical, fluid or thermal) use force, rate and resistance.

3. Before introducing any Ohm's laws, have students predict the affects of increasing forces, rates or resistance on any of the examples they have brought to class. Then have groups develop

ideas on how to predict the result of any increase or decrease in force, rate or resistance. These ideas will form the basis of Ohm's laws.

4. Assignment sheet 4.1 tests student knowledge of current, voltage and resistance. If desired, the instructor could use questions from this assignment sheet for Lessons 2 and 3, as appropriate.

B. Suggested supplemental materials

1. Bruce, David. Modern Electronic Basics, Devices and Applications. Reston, Va.: Reston Publishing Co., Inc., Prentice-Hall, 1984.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

LESSON 1: POWER SOURCES

NOTE: Electric energy found in nature (lightning) is not in a usable form. Electric energy must be converted from other energy sources. Understanding sources from which electric energy can be obtained is necessary as more electronic devices become portable and less dependent upon the common battery.

I. Terms and definitions

   A. Battery--one or more cells

   B. Cell--device that changes chemical energy into electrical energy

   C. Crystal--piezoelectric device that changes mechanical energy into electrical energy

   D. Energy convertor--device that changes one form of energy to another

   E. Generator--device that changes mechanical energy into electrical energy

   F. Motor--the inverse of a generator; it converts electric energy into mechanical energy

   G. Parallel sources--a type of circuit arrangement that increases the current capability to the circuit

   H. Photoelectric--electrical device capable of responding to light

   I. Power source--device capable of providing energy to a circuit

   J. Primary cell--cell that is not designed to be recharged (the common "D" cell for flashlights)

   K. Secondary cell--cell that is designed to be recharged (automobile battery)

   L. Series-aiding sources--a type of circuit arrangement that increases the voltage supplied and power delivered to the circuit

   M. Series-opposing sources--a type of circuit arrangement that decreases voltage supplied to the circuit.

   N. Thermocouple--device that changes thermal (heat) energy into electrical energy

II. Safety considerations

   A. Primary cells

      1. Not meant to be recharged

      2. Charging primary cells can cause problems.

         a. Leakage, explosion, exposure to caustic materials

         b. Injury to people and components

B. Secondary cells (designed to be recharged)
   1. The proper rate of recharging must be controlled.
   2. Improper recharging of secondary cells can be hazardous.
      a. Battery explosion and shortened useful life
      b. Injury to people

POWER SOURCES

Fill in the blanks with the appropriate answers.

1. The ___________ converts chemical energy into electric energy.
2. The ___________ converts thermal energy into electric energy.
3. The ___________ , also called piezoelectric, converts mechanical energy into electrical energy.
4. ___________ describes an electric device that responds to light.
5. When a cell is designed to be recharged, it is called a ___________ .
6. List two results of recharging a primary cell.

   a.

   b.

7. Connecting energy sources in ______________ will increase the current capability to a circuit.
8. Connecting energy sources in ______________ will increase the voltage to the circuit.

ANSWERS TO AS 1.1

1. Battery (cell)
2. Thermocouple
3. Crystal
4. Photoelectric
5. Secondary cell
6. Any two of the following (or similar responses):
   Leakage of the chemicals
   Exposure to caustic materials
   Shortened useful life of the cell
   Injuries to people
   Possible explosion of the cell
   Damage to the cell
7. Parallel
8. Series aiding

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

LESSON 2: CURRENT

NOTE: Electricity involves many things working together--specifically, current, voltage, resistance and power (electrical quantities). However, to use information about a circuit or an electrical device one needs to understand what each quantity means. This lesson covers current.

I. Terms and definitions

- A. Ampere (amp)--rate at which one coulomb of charge (electrons or ions) moves past a point in one second
- B. Charge--quantity of electricity measured in coulombs
- C. Coulomb--quantity of charge of 6.25×10^{18} electrons
- D. Current--movement of charge (electrons or ions) per unit of time

II. Common quantities and symbols related to current

Quantity	Symbol	Unit	Symbol
Current	I (intensity)	Ampere	A
Charge	Q (quantity)	Coulomb	C

- A. Amp
  1. One amp = one coulomb of electrons moving past a point in one second
  2. $1A = 1C \div 1sec$
  3. $2A = 2C \div 1sec$
  4. $2A = 1C \div .5sec$
- B. Coulomb
  1. 6.25×10^{18} electrons
  2. 6,250,000,000,000,000,000 electrons
- C. Current carriers
  1. Electrons are current carriers in solids (e.g. wires), liquids (salt water) and gases (neon lamps).
  2. Ions are current carriers in liquids and gases only.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

LESSON 3: VOLTAGE

NOTE: Just as with current, voltage is a fundamental part of the study of electronics. Understanding exactly what voltage is and what it causes to happen in a circuit is essential to all electronic technicians.

I. Terms and definitions

  A. Voltage--the force-like quantity of electricity; similar to pressure in fluids

  B. Joule--a unit of energy

  C. Volt--base unit to measure voltage. One volt is defined as one joule per coulomb.

  D. Electromotive force (EMF)--description of the voltage produced at a source (e.g. battery or generator)

  E. Polarity--negative or positive; a comparison of the relative value of the potential at one point compared to another point

  F. Potential difference (Pd)--description of the difference in voltage between two points in a circuit

II. Voltage concepts

Quantity	Symbol	Unit	Symbol
Voltage	V, E, Pd, EMF	Volt	V
Charge	Q	Coulomb	C
Energy (work)	W	Joule	J

  A. The volt

    1. One volt = one joule of energy per coulomb of electrons

    2. $1V = 1J \div 1C$

  B. Voltage and polarity

    1. Voltage (potential difference) is the relative difference between two points.

    2. Polarity may be positive or negative when compared to ground or another point.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

LESSON 4: RESISTANCE

NOTE: Resistance is the third fundamental part of the study of electronics.
At times resistance is useful and valuable. At other times it may cause overheating and inefficiency in circuits. It is, however, always a part of every electronic and an important concept for the technician to master.

I. Terms and definitions

- A. Resistance--opposition to the flow of current caused by voltage
- B. Resistor--name given to a component that resists current flow
- C. Ohm--base unit of resistance
- D. Conductance--inverse of resistance. A component with high resistance has low conductance, and a component with low resistance has high conductance.
- E. Specific resistance (resistivity)--resistance characteristic of a material; every material (copper, aluminum, gold, etc.) has a specific resistance

II. Common quantities and symbols related to resistance

Quantity	Symbol	Unit	Symbol
Resistance	R	Ohm	Ω
Conductance	G	Siemens	S

III. Resistance concepts

- A. The ohm
    - 1. One ohm is the amount of resistance that allows one amp of current to flow through a component that has one volt across that component.
    - 2. 1Ω = 1V ÷ 1A
    - 3. 2Ω = 2V ÷ 1A
    - 4. 2Ω = 1V ÷ .5A
- B. Resistance
    - 1. Resistance is determined by several factors.
        - a. Material make-up
        - b. Cross-sectional area (how thick or big the component is)
        - c. Length (how long the component is)
        - d. Temperature (how hot or cold the component is)

AS 4.1

CURRENT, VOLTAGE AND RESISTANCE

Fill in the blanks with the appropriate answer.

Current

1. A quantity of electrons is called ______________ .
2. 6.25×10^{18} electrons is the description of the unit called __________ .
3. While current can be movement of electrons or ions, in solid wire it can be only ______________ .
4. Ions can be the current carriers in gasses and _______________ .
5. One coulomb per second is the definition of a(n) ______________ .

Voltage

6. List all the abbreviations/symbols for voltage. __________________
7. The unit for voltage is the ________ , and its symbol is ____ .
8. Voltage at one point in a circuit compared to a second point in a circuit can be __________ or __________ polarity.
9. The symbol for electromotive force is ________ .
10. While V can be used to indicate voltage or the unit volt, E is used as a symbol only for ______________ .

Resistance

11. Write the letter symbol for resistance. ________
12. The unit of resistance is the ________ , and the unit's symbol is ________ .
13. What four things determine the resistance of a component?
    a.
    b.
    c.
    d.
14. The inverse of resistance is ______________ and its letter symbol is ______ .

ANSWERS TO AS 4.1

1. Charge
2. Coulomb
3. Electrons
4. Liquids
5. Ampere
6. V, E, PD (Pd), EMF
7. Volt, V
8. Positive, negative
9. EMF
10. Voltage
11. R
12. Ohm, Ω
13. Resistivity (specific resistance)
    Length
    Cross-sectional area
    Temperature
14. Conductance, G

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

LESSON 5: POWER

NOTE: Power is the result of the first three fundamental parts of the study of electronics--current, voltage and resistance. Nearly every electronic device is labeled with a power rating. Being able to predict power usage and safely control power dissipation is part of every technician's job.

I. Terms and definitions

  A. Power (P)--a rate quantity; the rate of doing work

  B. Watt (W)--unit in which power is measured

  C. Power rating--amount of power that can be safely handled by a component; also the amount of heat that can be safely dissipated by a component

  D. Kilowatt-hour (KWH)--unit of energy (not power) used by the electric company to charge its customers for energy consumed

II. Quantities, symbols and concepts

Quantity	Symbol	Unit	Symbol
Power	P	Watt	W

  A. The watt

    1. One watt is equal to one joule of energy used per second.

    2. $1W = 1J \div 1sec$

    3. Power (measured in watts) is equal to volts times amps.

    4. $P = V \times I$

  B. Power ratings

    1. Resistors ratings

      a. Common ratings sizes

      b. Physical size is directly related to the power rating.

    2. Other components: transistors and lamps (75 watt, 100 watt)

AS 5.1

POWER

Fill in the blanks with the appropriate answer.

1. Power is the rate of ________________ per amount of time (second).
2. The symbol for power is ________ .
3. The unit used for power is the ________ .
4. The symbol for the unit of power is ________ .
5. The electric company sells its customers ___________ , not power.
6. Power is also called the rate of doing ________ .
7. Power can be calculated by multiplying __________ and ________ .

ANSWERS TO AS 5.1

1. Work done
2. P
3. Watt
4. W
5. Energy
6. Work
7. Current, voltage

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

LESSON 6: PROPORTIONALITY AND SCHEMATIC SYMBOLS

NOTE: When forces are increased, other things are also affected. When the accelerator petal is pressed, the engine delivers more force to the wheels and the rate of motion of the vehicle is increased. The quantities of current, voltage and resistance are proportional. This lesson will introduce the idea that changing one quantity affects another.

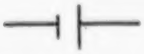
This lesson also introduces the first three schematic symbols. Most information supplied by manufacturers about circuits are in the form of schematic diagrams rather than pictorials.

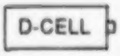
I. Terms and definitions

- A. Direct proportion (directly proportional)--when one quantity that can change causes another quantity to change in the same manner (bigger or smaller)
- B. Inverse proportion (inversely proportional)--when one quantity that can change causes another quantity to change in the opposite manner (first quantity increasing causes another quantity to decrease)
- C. Schematic diagram--description of a circuit composed entirely of symbols that designate specific components (Pictorial drawings are not normally used except to clarify unusual situations.)
- D. Pictorial--type of drawing that is a sketch of what a device actually looks like

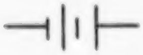
II. Schematic symbols and pictorials

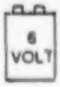
- A. Cell



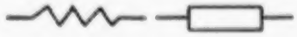


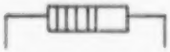
- B. Battery





- C. Resistor





RELATIONSHIP OF VOLTAGE, CURRENT, RESISTANCE AND POWER

Circle the appropriate answer.

1. If an automobile increases its rate (in mph), the engine is delivering more force to the wheels. This is an example of (direct/inverse) proportionality.

2. Wind striking an automobile increases from 10 mph to 30 mph. Unless the driver pushes more on the petal, the automobile will (increase/decrease) in its rate (speed in mph).

3. The situation in #2 above is an example of (direct/inverse) proportionality.

4. Rate and resistance are inversely proportional. This means that if resistance decreases, rate will (increase/decrease).

5. Rate and force are directly proportional. This means that if a force decreases, the rate will (increase/decrease).

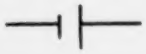
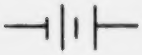
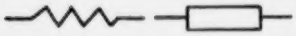
Draw symbols designating the following components.

____ 6. Cell

____ 7. Battery

____ 8. Resistor

ANSWERS TO AS 6.1

1. Direct
2. Decrease
3. Inverse
4. Increase
5. Decrease
6. 
7. 
8. 

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT II: BASIC CONCEPTS AND SOURCES OF ELECTRICAL QUANTITIES

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Which is a device that converts thermal energy to electrical energy?

a. Battery
b. Piezoelectrical device
c. Thermocouple
d. Generator
e. Any of the above

____ 2. Which device converts chemical energy to electrical energy?

a. Battery
b. Piezoelectrical device
c. Thermocouple
d. Generator
e. Any of the above

____ 3. A battery __________ .

a. Converts mechanical energy to electrical energy
b. Converts thermal energy to electrical energy
c. Consists of one or more cells
d. Consists of two or more cells
e. Converts thermal energy to nuclear energy

____ 4. When electrical sources are connected in a series-aiding manner, what is increased?

a. Current capability
b. Voltage
c. Power delivered
d. Resistance in the circuit
e. b and c

____ 5. When electrical sources are connected in a parallel manner, what is increased?

a. Current capability
b. Voltage
c. Power delivered
d. Resistance in the circuit
e. None of the above

____ 6. With which of the following can electrical energy be converted from mechanical energy?

a. Piezoelectrical device
b. Generator
c. Crystal
d. All of the above
e. None of the above

____ 7. Primary cells are __________ .

a. Designed to be recharged
b. Not designed to be recharged
c. Thermal energy convertors
d. All of the above
e. None of the above

____ 8. Secondary cells are ___________ .

a. Used in automobiles
b. Designed to be recharged
c. Not designed to be recharged
d. Both a and b
e. All of the above

____ 9. Solar cells provide power to devices like calculators. Solar cells are __________ .

a. Thermocouples
b. Generators
c. Electromagnetic
d. Photoelectric
e. None of the above

____ 10. Charging a run-down primary cell can __________ .

a. Safely result in a useful battery
b. Damage the cell
c. Cause a hazard for the user
d. Both b and c
e. None of the above

____ 11. How is electron current defined?

a. Protons from a negative polarity to a positive polarity
b. Protons from a positive polarity to a negative polarity
c. Electrons from a negative polarity to a positive polarity
d. Electrons from a positive polarity to a negative polarity
e. None of the above

____ 12. Which is the unit of electrical charge?

a. Volt
b. Current
c. Ampere
d. Coulomb
e. None of the above

____ 13. An ampere is equal to ___________ .

a. One volt per second
b. One coulomb
c. One coulomb per volt
d. Coulomb per second
e. Coulomb per minute

____ 14. Current can consist of the net movement of __________ .

a. Ions
b. Positrons or negatrons
c. Electrons
d. Protons or neutrons
e. Electrons and ions

____ 15. Current in electrical wires is the movement of __________ .

a. Electrons or ions
b. Positrons or negatrons
c. Electrons only
d. Protons or neutrons
e. Electrons or neutrons

____ 16. A coulomb is a unit of __________ .

a. Current
b. Charge
c. Voltage
d. Power
e. None of the above

____ 17. Charge is a __________ .

a. Unit of current
b. Unit of power
c. Quantity of atoms
d. Quantity of electrons
e. None of the above

____ 18. Current is the __________ .

a. Force of an electron
b. Unit of power
c. Rate of charge moved past a point
d. Rate of energy used
e. None of the above

____ 19. Which of the following describes ions?

a. Individual neutrons without protons
b. Individual protons without neutrons
c. Unbalanced atoms
d. All of the above
e. None of the above

____ 20. What is present when 6.25×10^{18} electrons move past a point in one second?

a. Ampere
b. Volt
c. Coulomb
d. Watt
e. None of the above

____ 21. Voltage is a(n) __________quantity.

a. Rate
b. Force-like
c. Resistance
d. Energy
e. Unknown

____ 22. One volt is one __________ .

a. Joule per coulomb
b. Coulomb per amp
c. Joule per ohm
d. Joule per watt
e. Coulomb per second

____ 23. A commonly used term for voltage is EMF. What does EMF stand for?

a. Electromechanical
b. Electrostatic magnetic
c. Electromagnetic
d. Electromotive
e. None of the above

____ 24. A symbol for voltage is V. What is another letter sometimes used?

a. I
b. R
c. E
d. P
e. G

____ 25. To determine the voltage in a circuit, __________ .

a. Only one point must be considered
b. Two points must be compared
c. At least three points must be compared
d. The power should be turned off
e. Compare one point and turn off power

____ 26. The voltage in a circuit can be __________ .

a. Positive only with respect to ground
b. Negative only with respect to ground
c. Positive or negative with respect to ground
d. Positive or negative, but only one can exist in a single circuit
e. None of the above

____ 27. Which is another commonly used description for voltage?

a. Potential difference
b. Power difference
c. I ÷ R
d. Electrostatic interference
e. None of the above

____ 28. Which is the symbol for unit of volt?

a. I
b. E
c. R
d. V
e. T

____ 29. Which of the items below is not correct for voltage?

a. EMF
b. Potential difference
c. Joule per coulomb
d. Rate of electron flow
e. All of the above

____ 30. Voltage in a circuit is a description of the __________ .

a. Rate of electrons moving through a conductor
b. Amount of energy used
c. Heat produced by the circuit
d. Difference in potential between two points
e. None of the above

____ 31. Resistance is the opposition to which of the following?

a. Flow of current
b. Flow of voltage
c. Amount of power
d. Quantity of energy in a circuit
e. None of the above

____ 32. The unit of resistance is __________ .

a. Resistor
b. Ohm
c. Coulomb
d. Joule
e. None of the above

____ 33. Which is the symbol for resistance?

a. R
b. Ω
c. I
d. V
e. μ

____ 34. How well a material conducts is referred to as __________ .

a. Conductance
b. Reciprocance
c. Invertance
d. Resistivity
e. None of the above

____ 35. While some elements are good conductors, insulators are usually __________ .

a. Other elements
b. Mixtures
c. Compounds
d. All of the above
e. None of the above

____ 36. Four factors affect resistance. What are they?

a. Length, voltage, temperature and resistivity
b. Length, cross-sectional area, current and resistivity
c. Energy, cross-sectional area, temperature and resistivity
d. Length, cross-sectional area, temperature and material
e. None of the above

____ 37. How is the ohm symbolically represented?

a. Ω
b. E
c. R
d. μ
e. π

____ 38. One volt divided by one ampere is equal to one __________ .

a. Ohm
b. Siemens
c. Resistor
d. Coulomb
e. None of the above

____ 39. Power is a rate of __________ .

a. Voltage applied
b. Current drawn
c. Charge moved
d. Work done
e. Voltage discharged

____ 40. Which is the symbol for power?

a. W
b. E
c. Q
d. P
e. R

____ 41. Which is the unit of power?

a. Ohm
b. Volt
c. Amp
d. Watt
e. None of the above

____ 42. Power is a __________ .

a. Force-like quantity
b. Quantity of energy
c. Rate of doing work
d. Both b and c
e. All of the above

____ 43. Force and rate are directly proportional. If rate is increased, force has __________ .

a. Increased
b. Decreased
c. Remained the same
d. Increased or decreased; cannot tell without other information
e. None of the above

____ 44. What determines a carbon-composition resistor's power rating?

a. Length of wire leads
b. Color code
c. Tolerance
d. Physical size
e. All of the above

____ 45. The unit of power's symbol is __________ .

a. I
b. R
c. P
d. W
e. Ω

____ 46. Increasing the resistance in a volume control circuit will decrease the volume at the speaker. What is this an example of?

a. Direct proportionality
b. Inverse proportionality
c. Inherent proportionality
d. Convergent proportionality
e. None of the above

ANSWERS TO UNIT TEST

1.	c	(B6)
2.	a	
3.	c	
4.	e	(B8)
5.	a	(B8)
6.	d	
7.	b	
8.	d	
9.	d	(B5)
10.	d	
11.	c	(B8)
12.	d	(B8)
13.	d	(B8)
14.	c	(B8)
15.	c	(B8)
16.	b	(B8)
17.	d	(B8)
18.	c	(B8)
19.	c	(B8)
20.	a	(B8)
21.	b	(B8)
22.	a	(B8)
23.	d	(B8)
24.	c	(B8)
25.	b	(B8)
26.	c	(B8)
27.	a	(B8)
28.	d	(B8)
29.	d	(B8)
30.	d	(B8)
31.	a	(B7)
32.	b	(B7)
33.	a	(B7)
34.	a	(B8)
35.	c	(B8)
36.	d	(B7)
37.	a	(B8)
38.	a	(B8)
39.	d	(B8)
40.	d	(B8)
41.	d	(B8)
42.	c	(B8)
43.	a	(B8)
44.	d	(B8)
45.	d	(B8)
46.	b	(B8)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT III: OHM'S LAW

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to use Ohm's Law and the power formulas to find an unknown value when given two of the following: current, voltage, resistance or power. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Use basic Ohm's Law formulas to solve for an unknown when given two of three quantities. (partial competency B8)

2.1 Use appropriate formulas relating current, voltage, resistance and power to solve problems. (partial competency B8)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT III: OHM'S LAW

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to instructor

D. Lesson plans

1. Lesson 1: INTRODUCTION
    - a. Information outline
    - b. Assignment sheets

        AS 1.1: Computing volts with Ohm's Law
        AS 1.2: Computing amps with Ohm's Law
        AS 1.3: Computing ohms with Ohm's Law

    - c. Answers to assignment sheets

2. Lesson 2: POWER AND RELATED FORMULAS
    - a. Information outline
    - b. Assignment sheets

        AS 2.1: Computing watts using volts and amps
        AS 2.2: Computing watts using volts and ohms
        AS 2.3: Computing watts using amps and ohms
        AS 2.4: Computing amps using watts and ohms

    - c. Answers to assignment sheets

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.

2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

3. Graf, Rudolf F. Modern Dictionary of Electronics. 6th ed. Indianapolis, IN: Howard W. Sams & Co., Inc., 1984.

4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

5. Schuler, Charles A.; Richard J. Fowler. Basic Electricity and Electronics. St. Louis: McGraw-Hill, 1988.

B. Curriculum guides

1. Hartman, Lonnie. Basic Electronics. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

2. Robertson, L. Paul. Basic Electronics I. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1980.

3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. The concepts of direct and inverse proportionality have already been discussed. This unit will deal directly with Ohm's Law.

2. Specific power formulas will be introduced in Lesson 2, as will the entire group of formulas relating current, voltage, resistance and power--each in terms of the other two quantities.

B. Suggested supplemental materials

1. Bruce, David. Modern Electronic Basics, Devices and Applications. Reston, Va.: Reston Publishing Co., Inc., Prentice-Hall, 1984.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT III: OHM'S LAW

LESSON 1: INTRODUCTION

I. Ohm's Law--the basic description indicating how current, voltage and resistance affect and/or control each other

  A. Useful in electronics since the relation between current, voltage and resistance is fixed; it is predictable and will not change.

    1. Technicians can use this fact to predict what a circuit will (or should) do. Knowing what a circuit should do is the first key step in troubleshooting any electronic circuit.

    2. A technician must be so sure of his/her prediction of what the circuit should do (analysis) that when a meter reading is different than the prediction, the technician knows that something is wrong with the circuit.

  B. The first steps of circuit analysis involve predicting results of the circuit quantities of current, voltage and resistance.

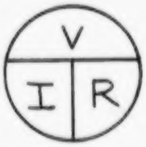
  C. Three versions of the basic Ohm's Law formula

    1. $V = I \times R$

    2. $I = V \div R$

    3. $R = V \div I$

  D. The wheel chart



COMPUTING VOLTS WITH OHM'S LAW

Use the appropriate formula to solve the following problems.

	AMPS	OHMS	VOLTS
1.	20	6	____
2.	4	60	____
3.	9.5	12	____
4.	80	.5	____
5.	.1	1000	____
6.	.05	50	____
7.	1.5	1200	____
8.	2.5	470	____
9.	3.6	3300	____
10.	.0022	1000	____

COMPUTING AMPS WITH OHM'S LAW

Use the appropriate formula to solve the following problems.

	VOLTS	OHMS	AMPS
1.	240	12	____
2.	110	11	____
3.	440	20	____
4.	120	30	____
5.	24	3	____
6.	12	1	____
7.	.005	1	____
8.	.2	.004	____
9.	20,000	50,000	____
10.	7260	22	____

AS 1.3

COMPUTING OHMS WITH OHM'S LAW

Use the appropriate formula to solve the following problems.

	VOLTS	AMPS	OHMS
1.	240	4	_____
2.	24	9.6	_____
3.	12	5	_____
4.	230	5	_____
5.	24	8	_____
6.	12	.002	_____
7.	5	.2	_____
8.	1000	.05	_____
9.	.2	.5	_____
10.	240	20	_____

ANSWERS TO AS 1.1

1. 120
2. 240
3. 114
4. 40
5. 100
6. 2.5
7. 1800
8. 1175
9. 11,880
10. 2.2

ANSWERS TO AS 1.2

1. 20
2. 10
3. 22
4. 4
5. 8
6. 12
7. 0.005
8. 50
9. 0.4
10. 330

ANSWERS TO AS 1.3

1. 60
2. 2.5
3. 2.4
4. 46
5. 3
6. 6000
7. 25
8. 20K or 20,000
9. 0.4
10. 12

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT III: OHM'S LAW

LESSON 2: POWER AND RELATED FORMULAS

NOTE: While Ohm's Law defines how current, voltage and resistance are related, additional formulas are needed when power is part of the troubleshooting analysis. This lesson will provide all the necessary equations for power and the complete set of equations for finding a missing quantity (current, voltage, resistance or power) when the other two quantities are known.

I. Terms and definitions

   A. Power formulas--the basic description of how current, voltage and resistance affect power in a circuit

   B. Additional relationships--a combination of the Ohm's Law formulas and the power formulas

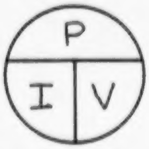
II. Power formulas

   A. $P = I \times V$

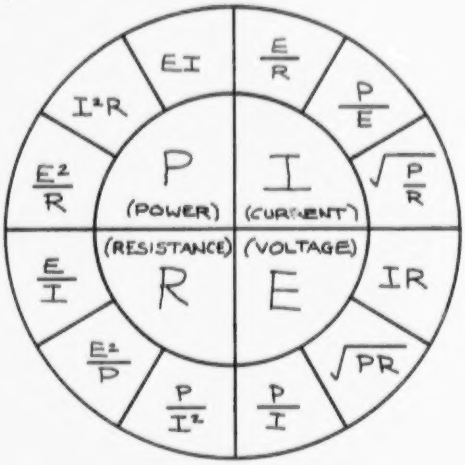
   NOTE: E and V are sometimes used interchangeably in formulas.

   B. $P = I^2 \times R$

   C. $P = V^2 \div R$



III. Complete wheel chart of formulas



COMPUTING WATTS USING VOLTS AND AMPS

Use the appropriate formula to solve the following problems.

	VOLTS	AMPS	WATTS
1.	30	2	____
2.	15	4	____
3.	1000	.05	____
4.	2	.002	____
5.	1.5	.5	____
6.	240	.1	____
7.	24	1	____
8.	2.4	10	____
9.	2400	.01	____
10.	20,000	.1	____

AS 2.2

COMPUTING WATTS USING VOLTS AND OHMS

Use the appropriate formula to solve the following problems.

	VOLTS	OHMS	WATTS
1.	30	10	____
2.	24	5	____
3.	120	100	____
4.	5	470	____
5.	12	220	____
6.	24	180	____
7.	16	1500	____
8.	1.5	12	____
9.	440	20	____
10.	7260	1200	____

COMPUTING WATTS USING AMPS AND OHMS

Use the appropriate formula to solve the following problems.

	AMPS	OHMS	WATTS
1.	2	10	____
2.	4	10	____
3.	8	10	____
4.	.1	10	____
5.	20	.05	____
6.	15	.1	____
7.	.2	5	____
8.	.03	120	____
9.	.025	1500	____
10.	.08	22,000	____

AS 2.4

COMPUTING AMPS USING WATTS AND OHMS

Use the appropriate formula to solve the following problems.

	WATTS	OHMS	AMPS
1.	20	100	____
2.	5	2200	____
3.	2	1000	____
4.	0.5	470	____
5.	0.25	10,000	____

	WATTS	OHMS	VOLTS
6.	20	100	____
7.	5	2200	____
8.	2	1000	____
9.	0.5	470	____
10.	0.25	10,000	____

	AMPS	VOLTS	WATTS
11.	20	100	____
12.	5	2200	____
13.	2	1000	____
14.	0.5	470	____
15.	0.25	10,000	____

ANSWERS TO AS 2.1

1. 60
2. 115.2
3. 50
4. 0.0532W
5. 0.75
6. 24
7. 24
8. 24
9. 24
10. 43,923

ANSWERS TO AS 2.2

1. 90
2. 115.2
3. 144
4. 0.53
5. 0.6545
6. 3.2
7. 0.1706
8. 0.1875
9. 9680
10. 43,923

ANSWERS TO AS 2.3

1. 40
2. 160
3. 640
4. 0.1
5. 20
6. 22.5
7. 0.2
8. 0.108
9. 0.9375
10. 140.8

ANSWERS TO AS 2.4

1. 0.447
2. 0.0477
3. 0.0447
4. .0326
5. 0.005
6. 44.7
7. 104.88
8. 44.7
9. 15.33
10. 50
11. 2,000
12. 11,000
13. 2,000
14. 235
15. 2.5K or 2500

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT III: OHM'S LAW

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. The formula used to find voltage, when current and resistance are known, is _________ .

- a. $V = I \times R$
- b. $V = I \div R$
- c. $V = I \times I \times R$
- d. $V = I \times I \div R$
- e. $V = (I + R) \div 2$

____ 2. A 100Ω resistor with 0.2 amps going through it will have _________ across it.

- a. 200V
- b. 20V
- c. 2V
- d. 0.2V
- e. -2V

____ 3. The formula used to find current, when voltage and resistance are known, is _______ .

- a. $I = V \times R$
- b. $I = V \div R$
- c. $I = R \div V$
- d. $I = V \times V \div R$
- e. $I = (V + R) \div 2$

____ 4. A 220Ω resistor has 15V across it. It conducts _________ of current.

- a. 330A
- b. 14.7A
- c. 0.068A
- d. 1.02A
- e. -1.02A

____ 5. The formula used to find resistance, when current and voltage are known, is _______ .

- a. $R = V \times I$
- b. $R = V \div I$
- c. $R = I \div V$
- d. $R = I \times I \times V$
- e. $R = (V + I) \div 2$

____ 6. A resistor has 0.1A through it and 10V across it. It is a(n) _________ resistor.

- a. 1Ω
- b. 0.1Ω
- c. 0.01Ω
- d. 100Ω
- e. 10Ω

____ 7. The formula used to find power, when current and voltage are known, is _______ .

- a. $P = V \times I$
- b. $P = V \div I$
- c. $P = V \times V \div I$
- d. $P = I \times I \times V$
- e. $P = (V + I) \div 2$

____ 8. A component has 5V across it and 2A through it. It dissipates ____ of power.

a. 10W
b. 2.5W
c. 12.5W
d. 20W
e. 22.5W

____ 9. A component has 10V across it and has 20Ω of resistance. It dissipates ________ of power.

a. 220W
b. 100W
c. 5W
d. 2000W
e. 20W

____ 10. A component has 2A through it and has 10Ω of resistance. It dissipates ________ of power.

a. 20W
b. 0.2W
c. 40W
d. 0.4W
e. 2W

____ 11. A 100Ω resistor is dissipating 1W of power. The voltage across it is ________ .

a. 1V
b. 0.1V
c. 100V
d. 10V
e. 10.5V

____ 12. A 10Ω resistor is dissipating 0.1W of power. The current through it is ________ .

a. 0.1A
b. 1A
c. 0.0316
d. 3.16A
e. 2.31A

____ 13. A 12Ω resistor is dissipating 12W of power. The voltage across it is ________ .

a. 1V
b. 10V
c. 12V
d. 144V
e. 150V

____ 14. A component with 1A through it and 12V across it has a resistance of ________ .

a. 12Ω
b. 0.833Ω
c. 11Ω
d. 13Ω
e. 144Ω

____ 15. A 1Ω resistor with 1A through it dissipates 1W of power. If the current increases to 2A, the power dissipated is ________ .

a. 2W
b. 4W
c. 0.5W
d. 1.414W
e. 6W

ANSWERS TO UNIT TEST (B8)

1. a
2. b
3. b
4. c
5. b
6. d
7. a
8. a
9. c
10. c
11. d
12. a
13. c
14. a
15. b

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IV: UNITS AND CONVERSIONS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to use the standard and prefixed units for basic electrical quantities. The student should also be able to use a basic scientific calculator for calculations involving scientific or engineering notation. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Identify unit and conversion terms.

1.2 Identify notation types and symbols. (partial competency B17)

1.3 Convert between scientific, engineering and decimal notation when describing a quantity.

2.1 Identify calculation terms used with a scientific calculator.

2.2 Use a basic scientific calculator to perform calculations involving scientific, engineering and decimal notation.

2.3 Calculate problems involving multiple operations. (prerequisites for competencies B15 and B18)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IV: UNITS AND CONVERSIONS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to instructor

D. Lesson plans

  1. Lesson 1: BASIC UNITS

    a. Information outline

    b. Handout

      HO 1.1: Engineering and scientific notations

    c. Assignment sheet

      AS 1.1: Converting to engineering and scientific notations

    d. Answers to assignment sheet

  2. Lesson 2: CALCULATIONS

    a. Information outline

    b. Assignment sheets

      AS 2.1: Calculating problems with engineering notations
      AS 2.2: Calculating problems with decimal notation

    c. Answers to assignment sheets

E. Unit test

F. Answers to unit test

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A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.

2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

3. Graf, Rudolf F. Modern Dictionary of Electronics. 6th ed. Indianapolis, IN: Howard W. Sams & Co., Inc., 1984.

4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

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1. Hartman, Lonnie. Basic Electronics. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

2. Robertson, L. Paul. Basic Electronics I. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1980.

3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. This unit covers prerequisite knowledge for the student to complete competencies B15 and B18.

2. Methods of describing and communicating the values of electrical quantities are, of course, important. (Voltage, current, resistance and power are addressed in this unit.) Some textbooks emphasize scientific notation and then proceed to use SI units (of which engineering notation is a part) almost exclusively. Because the Systeme International d'Unites is the accepted standard, this unit will emphasize engineering notation. While scientific notation is covered, engineering notation is the more important.

3. Methods used to (1) convert from one unit prefix to another, (2) place the number of a problem into a specific calculator for correct results and (3) move the decimal point for correct engineering or scientific notation will vary. A standard method that can be universally applied is important. Chemists and pharmacists use very exacting methods for conversions and for keeping track of significant digits in a calculation. They are good sources for excellent applied methods (as opposed to abstract methods) for unit conversions.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IV: UNITS AND CONVERSIONS

LESSON 1: BASIC UNITS

NOTE: Information that is vital to the technician is usually supplied in a very technical way. Manufacturers of electronic equipment expect people who read their information to understand technical terms and abbreviations. This unit will introduce methods of writing technical information.

I. Terms and definitions

   A. Ampere (amp)--unit of current

   B. Decimal notation--used most often by non-technical people; method of writing a number without adjusting the position of the decimal point

   C. Engineering notation--used by the electrical field almost exclusively; a method of writing a number so that the value of the number is always between 1 and 999 (including those numbers). The value of the number is not changed because engineering prefixes adjust the unit. (For example, 4/1000 volts or 0.004 volts is the same as four millivolts because "milli" adjusts the unit of volt to mean one-thousandth of a volt.)

   D. Notation--how a number is written

   E. Ohm--unit of resistance

   F. Prefix--part of a word indicating by what amount a number is adjusted or changed

   G. Quantity--description of a specific part of an electrical circuit such as voltage, current, resistance, power, charge, etc.

   H. Scientific notation--used in the scientific and research areas; a method of writing a number so that the value of the number is always between one and nine (including those numbers). The value of the number is not changed because scientific notation uses a power of 10 to adjust the unit (e.g. 200 watts is the same as 2×10^2 watts).

   I. SI (Systeme' International)--internationally accepted method of writing and documenting information; also referred to as the metric system

   J. Unit--specific amount used to measure a quantity (For example, a distance quantity can be measured in miles; a current quantity can be measured in amps.)

   K. Volt--unit of voltage

   L. Watt--unit of power

II. Notations (HO 1.1)

   A. Decimal notation

      1. A number describes an amount without using powers of 10 or prefixes for the units.

      2. The decimal point is not moved for any adjustment.

   B. Engineering notation (SI)

84

        1. The whole number part is between 1 and 999 (inclusive).
        2. The prefix of the units accounts for the decimal adjustment.
    C. Scientific notation
        1. The whole number part is between 1 and 9 (inclusive).
        2. A power of 10 accounts for the decimal adjustment.
III. Conversions
    A. Decimal and engineering
    B. Decimal and scientific
    C. Engineering and scientific

HO 1.1

ENGINEERING AND SCIENTIFIC NOTATIONS

Engineering notation

Prefix	Value	Power of ten	Symbol
Giga	1,000,000,000	10^9	G
Mega	1,000,000	10^6	M
Kilo	1,000	10^3	K
(none)	1	10^0	(none)
Milli	0.001	10^{-3}	m
Micro	0.000001	10^{-6}	μ
Nano	0.000000001	10^{-9}	n
Pico	0.000000000001	10^{-12}	p

Scientific notation

Power of ten	Value	Description
10^6	1,000,000	million
10^5	100,000	hundred thousand
10^4	10,000	ten thousand
10^3	1,000	thousand
10^2	100	hundred
10^1	10	ten
10^0	1	one
10^{-1}	0.1	tenth
10^{-2}	0.01	hundredth
10^{-3}	0.001	thousandth
10^{-4}	0.0001	ten-thousandth

AS 1.1

CONVERTING TO ENGINEERING AND SCIENTIFIC NOTATIONS

Convert the following.

	Number	Engineering	Scientific
1.	96,000,000V		
2.	0,00465J		
3.	12.34Ω		
4.	0.002167A		
5.	34A		
6.	45,000C		
7.	0.725A		
8.	12.5Ω		
9.	17,500V		
10.	0.00223A		

ANSWERS TO AS 1.1

1.	96MV	9.6×10^{7}V
2.	4.65mJ	4.65×10^{-3}J
3.	12.34Ω	1.234×10^{1}Ω
4.	2.167mA	2.167×10^{-3}a
5.	34A	3.4×10^{1}A
6.	45KC	4.5×10^{4}C
7.	725mA	7.25×10^{-1}A
8.	12.5Ω	1.25×10^{1}Ω
9.	17.5KV	1.75×10^{4}V
10.	2.23mA	2.23×10^{-3}A

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IV: UNITS AND CONVERSIONS

LESSON 2: CALCULATIONS

I. Terms and definitions

  A. Exponent--power of a number (e.g. 10^3, where 3 is the exponent)

  B. EE or EXP key--calculator key for entering exponents for the power of 10

  C. ENG--key on some calculators to automatically convert a number to engineering notation

  D. SCI--mode on some calculators to automatically display answers in scientific notation

II. Calculations with engineering or scientific notation

  A. With engineering notation, include the power of 10 indicated by the prefix of the number. (Example: 0.001A = 1mA)

  B. With scientific notation, include the power of 10 of the number. (Example: 0.001A = 1×10^{-3}A)

III. Calculations involving multiple operations

  A. Order of computation

    1. Operations within parenthesis

    2. Numbers raised to powers (and root functions)

    3. Multiplication and division (left to right)

    4. Addition and subtraction (left to right)

  B. Order of number entry into the calculator varies with type of calculator

AS 2.1

CALCULATING PROBLEMS WITH ENGINEERING NOTATION

Complete the following problems. Use the correct engineering notation for the answer. Example: An answer of 0.01A will be written 10mA for 10 milliamps.

1. 1mA x 4KΩ = __________V
2. 15V x 15mA = __________W
3. 7mA x 100Ω = __________V
4. 23A x 120V = __________W
5. 175mV x 3mA = __________W
6. 0.1mA x 1200Ω = ________V
7. 3.15V x 0.01A = __________W
8. 6µA x 2MΩ = __________V
9. 42µA x 0.77V = __________W
10. $67V^2$ ÷ 520Ω = __________W
11. 6V ÷ 1.2KΩ = __________A
12. 80W ÷ 100V = __________A
13. 120V ÷ 15A = __________Ω
14. 5.7KW ÷ 15A = __________V
15. 375mW ÷ 10mA = __________V
16. 0.2W ÷ 5V = __________ A
17. 0.022V ÷ 11mA = __________Ω
18. 16mW ÷ 8V = __________A
19. 3KW ÷ 250 = __________A
20. $300V^2$ ÷ 1KΩ = ________ W

CALCULATING PROBLEMS WITH DECIMAL NOTATION

Complete the following problems using standard decimal notation.

1. $\dfrac{100{,}000\Omega \times 150{,}000\Omega}{100{,}000\Omega + 150{,}000\Omega} =$ ____________________ Ω

2. $\dfrac{8000\text{W}}{2\text{A}^2} =$ ____________________ Ω

3. $\dfrac{1}{\dfrac{1}{150\Omega} \qquad \dfrac{1}{100\Omega}} =$ ____________________ Ω

4. $\dfrac{(35 + 24) \times 2}{\frac{1}{3}} =$ ____________________

5. $\dfrac{24 \times 56 + 16}{(72-64) \times 10} =$ ____________________

6. Using engineering notation, the answer to #1 is ____________________.

7. Using engineering notation, the answer to #2 is ____________________.

8. Using engineering notation, the answer to #3 is ____________________.

9. Using scientific notation, the answer to #4 is ____________________.

10. Using scientific notation, the answer to #5 is ____________________.

ANSWERS TO AS 2.1

1. 4V
2. 225mW
3. 700mV
4. 2.76KW
5. 525μW
6. 120mV
7. 31.5mW
8. 12V
9. 32.34μW
10. 8.63W
11. 5mA
12. 800mA
13. 8Ω
14. 380
15. 37.5V
16. 40mA
17. 2Ω
18. 2mA
19. 12A
20. 90W

ANSWERS TO AS 2.2

1. 60,000Ω
2. 2,000Ω
3. 60Ω
4. 354
5. 17
6. 60KV
7. 2KV
8. 60Ω
9. 3.54×10^2
10. 1.7×10^1

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IV: UNITS AND CONVERSIONS

UNIT TEST

Select the option which best answers the question or completes the statement.

___ 1. What is the base unit for voltage?

a. Ohm
b. Volt
c. Amp
d. Watt
e. Joule

___ 2. Which is the base unit for current?

a. Ohm
b. Volt
c. Amp
d. Watt
e. Joule

___ 3. Identify the base unit for resistance.

a. Ohm
b. Volt
c. Amp
d. Watt
e. Joule

___ 4. Expressed in engineering notation, the number 0.625A is ___________.

a. 6.25Ω
b. 6.25A
c. 6.25mA
d. 625mA
e. 625MA

___ 5. Which is the symbol for the prefix milli?

a. m
b. K
c. M
d. μ
e. p

___ 6. Which is the symbol for the prefix pico?

a. m
b. K
c. M
d. μ
e. p

____ 7. Identify the symbol for the prefix mega.

a. m
b. K
c. M
d. μ
e. p

____ 8. Converted to scientific notation, the number 35,000C is ____________ .

a. 3.5C
b. 3.5×10^3C
c. 35×10^4C
d. 3.5×10^4C
e. 35×10^4C

____ 9. Which is the engineering notation for 0.003A?

a. 3mA
b. 30mA
c. 300mA
d. 3KA
e. 0.3KA

____ 10. In engineering notation, 127Ω is __________ .

a. 127,000μΩ
b. 0.123KΩ
c. 127,000mΩ
d. 0.000127MΩ
e. 127Ω

____ 11. Which is the engineering notation for 1,200V?

a. 1,200V
b. 1.2KV
c. 0.012MV
d. 1,200,000mV
e. None of the above

____ 12. Which calculator key is used to enter exponents?

a. ENG
b. EE or EXP
c. SCI
d. M
e. None of the abov

____ 13. The number 3×10^{-3}V is scientific notation for which of the following?

- a. 0.03V
- b. 30V
- c. 3000V
- d. 3mV
- e. 0.03V

____ 14. The number $4.7 \times 10^{7}\Omega$ is scientific notation for which of the following?

- a. 47,000,000Ω
- b. 47,000Ω
- c. 4,700,000Ω
- d. 0.47MΩ
- e. None of the above

____ 15. What does the number 8.2×10^{-1}A express in scientific notation?

- a. 8.2mA
- b. 82mA
- c. 820mA
- d. .082mA
- e. 8.2A

____ 16. 37mA x 10mV = __________.

- a. 370W
- b. 37W
- c. 0.37W
- d. 37mW
- e. 370μW

____ 17. 5KW ÷ 2.50×10^{3}V = __________.

- a. 2KA
- b. 2A
- c. 2mA
- d. 2μA
- e. none of the above

____ 18. 48 ÷ (6+2) = __________.

- a. 10
- b. 4
- c. 8
- d. 6
- e. 30

____ 19. In order of computation, which is always the very first operation?

a. Addition
b. Multiplication
c. Powers of 10
d. Square roots and powers
e. Inside any parenthesis

____ 20. Which is the last operations in order of computation?

a. Multiplication and division
b. Addition and subtraction
c. Powers of 10
d. Square roots and powers
e. Inside any parenthesis

ANSWERS TO UNIT TEST

1.	b		11.	b
2.	c		12.	b
3.	a		13.	d
4.	d		14.	a
5.	a	(B17)	15.	c
6.	e	(B17)	16.	e
7.	c	(B17)	17.	b
8.	d		18.	d
9.	a		19.	e
10.	e		20.	b

INSTRUCTOR'S NOTE: This unit covers prerequisite knowledge for the student to complete competencies B15 and B18.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT V: USE OF MULTIMETERS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to describe the basic functions of a multimeter and to use a multimeter to measure voltage, current and resistance. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Identify terms and definitions.

1.2 Identify common types of multimeters.

1.3 Describe multimeter functions.

2.1 Identify terms and definitions.

2.2 Select appropriate meter ranges for analog and digital meters.

2.3 Read measurements using various types of meter scales.

2.4 Describe general steps used in preparing a multimeter for operation.

2.5 Measure the voltage drop in a DC circuit. (competency H2, JS 2.1)

2.6 Measure and compare current at two different voltage levels. (competency H2, JS 2.2)

2.7 Measure resistance with an ohmmeter. (competency H2, JS 2.3)

2.8 Compare amperage, voltage and resistance measurement characteristics. (partial competency B12)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT V: USE OF MULTIMETERS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to instructor

D. Lesson plans

  1. Lesson 1: MULTIMETER BASICS

    a. Information outline

    b. Assignment sheet

      AS 1.1: Multimeter use

    c. Answers to assignment sheet

  2. Lesson 2: MEASUREMENTS

    a. Information outline

    b. Transparency masters

      TM 2.1: Analog multimeter
      TM 2.2: Digital multimeter
      TM 2.3: Correct voltage measurements
      TM 2.4: Correct amperage measurements
      TM 2.5: Correct resistance measurements

    c. Assignment sheets

      AS 2.1: Read analog voltmeter and ammeter scales
      AS 2.2: Read analog ohmmeter scales

    d. Answers to assignment sheets

    e. Job sheets

      JS 2.1: Measure the voltage drop in a DC circuit
      JS 2.2: Measure and compare current at two different voltage levels
      JS 2.3: Measure resistance with an ohmmeter

E. Unit test

F. Answers to unit test

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A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.
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NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. The specific type of multimeter used will greatly affect how material is presented. A student will be able to more fully grasp fundamental aspects of multimeter use when required to use more than one brand.
2. Most employers expect proficiency in using both digital and analog meters. Again, required competence in using more than one model is most effective.
3. Students will tend to use digital meters exclusively. Activities to ensure competence in reading analog meters are necessary.

B. Suggested student activities

1. Before students complete Job Sheet 2.1, discuss the following in class.
    a. Measurement across the load and the source
    b. Voltmeter reading across the closed switch
    c. Difference of potential across the load, and whether or not the voltage drop occurs across the load or the wire

    d. Voltage reading across the open switch

2. The following questions can be used for discussion before students complete JS 2.2. Answers will vary depending on load used.

    a. Were the calculated values equal to the measured current?

    b. Is there more current at 1.5 vdc or at 3 vdc power source?

    c. With the same load, what happens to the current in a circuit when the voltage applied to the circuit is changed?

    d. What happens if the polarity of the power source is reversed?

    e. If a lamp was used as the load, did (or would) the lamp glow brighter when the voltage was increased? Why?

C. Suggested supplemental materials

1. Bruce, David. Modern Electronic Basics, Devices and Applications. Reston, Va.: Reston Publishing Co., Inc., Prentice-Hall, 1984.

2. "Color code chart (for) fixed resistors" (part #597-1715). Benton Harbor, MI: Heathkit Educational Systems, 1978.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT V: USE OF MULTIMETERS

LESSON 1: MULTIMETER BASICS

NOTE: Of all the tools used by an electronics technician, the basic multimeter is most important. A good technician must be confident in his/her ability to use a meter.

I. Terms and definitions

  A. Accuracy--how nearly the meter indicates a value compared to what the value actually is

  B. Function setting--position of a multimeter switch to select the quantity to be measured (e.g. voltage, current or resistance)

  C. Multimeter--machine that combines the circuitry necessary to measure voltage, current and resistance

  D. Multiplier--resistor that is placed in series with the meter movement; enables the meter to measure larger voltage amounts for the voltmeter

  E. Parallax error--an optical illusion when viewing a pointer on an analog meter at an angle. When the eye is not directly above the surface of the meter face, the pointer will appear to be at a different location on the scale, causing an inaccurate reading.

  F. Range setting--switch position on a multimeter to select a value at least as high as the expected measurement

  G. Sensitivity--how well a meter responds to voltage or current without changing the voltage or current value the meter is measuring

  H. Shunt--component or circuit (typically a resistor) that is in parallel with another circuit (typically the meter movement); enables the meter to measure larger amounts of current for the ammeter

II. Types of multimeters

  A. Analog meters

    1. VOM (volt-ohm meter): measures voltage, current and resistance

    2. VTVM (vacuum tube volt meter): a high sensitivity VOM

    3. TVM (transistorized volt-ohm meter): the modern, tubeless version of the VTVM (vacuum-tube volt meter)

    4. Subject to parallax error, which can be corrected with good use of mirror scale

  B. Digital meters

    1. Use direct numeric readouts (usually seven-segment displays)

    2. Extremely high sensitivity

    3. Not subject to parallax error

III. Multimeter functions

- A. Switch settings for measurement
    - 1. Voltage DC
    - 2. Voltage AC
    - 3. Current
    - 4. Resistance
- B. Range settings
    - 1. To select a value equal to or greater than what is being measured
    - 2. To obtain greatest accuracy, try to place the analog pointer in the middle of the analog scale.
    - 3. Digital meters
        - a. A flashing display indicates a value more than the meter can display.
        - b. Some set the range automatically (auto-ranging).
- C. General characteristics
    - 1. Voltmeters
        - a. Very high resistance (theoretically an open circuit)
        - b. Range increased by adding a multiplier (series) resistance
        - c. Meter probes connect across the circuit or component
    - 2. Ammeters
        - a. Very low resistance (theoretically zero resistance)
        - b. Range increased by adding a shunt (parallel) resistance
        - c. Meter probes placed in series with circuit or component
    - 3. Ohmmeters
        - a. Ohmmeters always use an internal power source (usually a battery).
        - b. Power must be disconnected from circuit or component.

AS 1.1

MULTIMETER USE

Fill in the blanks with the appropriate answers.

1. The two major types of multimeters are ______________ and ______________.
2. The three functions of a typical multimeter are to measure ___________ , __________ and __________ .
3. VOM stands for ________________________________ .
4. VTVM stands for ____________________________________ .
5. A transistorized voltmeter (TVM) is sometimes also called a ___________ .
6. A voltmeter should have ___________ resistance.
7. An ammeter should have _____________ resistance.
8. For an ohmmeter to work, it must have an internal _______________ .
9. The _______________ switch must be set to a value at least as high as that being measured.
10. Parallax error is a problem in the _______________ type of meter.

ANSWERS TO AS 1.1

1. Analog/digital
2. Voltage, current, resistance
3. Volt ohmmeter
4. Vacuum tube volt meter
5. VTVM
6. Infinite or high
7. Zero or low
8. Power source or battery
9. Range
10. Analog

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT V: USE OF MULTIMETERS

LESSON 2: MEASUREMENTS

NOTE: Measurement of voltage is, by definition, measurement of the potential difference between two points. The black probe is usually the reference point. However, the reference point is not necessarily ground or common.

I. Terms and definitions

- A. Effective voltage--description of AC voltage used for multimeters
- B. Probe--insulated wire lead attached to the meter
- C. RMS voltage--same as effective voltage

II. Meter ranges for analog and digital meters

CAUTION: Connect analog meter probes using proper polarity to avoid damage to the meter (negative meter probe to negative side of circuit; positive lead to positive side of circuit).

- A. DC voltage ranges
  - 1. Analog--2.5, 10, 50, 250, 1000 and 5000 volts (TM 2.1)

    NOTE: The ranges given are for a Simpson 260. For DC voltage measurements above 1000 volts, put the red lead into the 5000 volt DC terminal.

  - 2. Digital--200mV, 2, 20, 200 and 1000 volts (TM 2.2)
- B. AC voltage ranges
  - 1. Analog--2.5, 10, 50, 250, 1000 and 5000 volts

    NOTE: For AC voltage measurements above 1000 volts, put the red lead into the 5000 AC terminal.

  - 2. Digital--200mV, 2, 20, 200 and 750 volts
- C. DC milliamps range
  - 1. Analog--1mA, 10mA, 50mA, 100mA, 500mA and 10A
  - 2. Digital--200A, 2mA, 20mA, 2A and 10A

    NOTE: For measurements greater than one amp, plug the red lead into the 10A terminal.

- D. AC milliamps range

  NOTE: For measurements greater than one amp, plug the red lead into the 10A terminal.

  - 1. Analog--1mA, 10mA, 50mA, 100mA, 500mA and 10A
  - 2. Digital--200A, 2mA, 20mA, 2A and 10A

E. Ohm ranges

1. Analog--X1, X100, XK and X10K

2. Digital--0-200, 0-2K, 0-20K, 0-200K, 0-2M and 0-20M

III. Types of meter scales (TM 2.1, 2.2)

A. 2.5 volt AC scale--used to do nonlinear indications below two volts

B. DB scale--used for power level measurements

C. Ohm's scale--used for resistance measurements. Zero readings always indicate a short. Readings at the left-most side of the scale indicate infinite resistance or an open.

D. DC scale--used for direct current/voltage measurements

E. AC scale--used for alternating current/voltage readings

IV. General steps used in preparing a multimeter for operation

A. Select function to be measured.

Examples: Volts, amps, milliamps, ohms, megohms

B. Select the range or anticipated limits of measurement required.

Examples: 500 mA, 20V or X100Ω

NOTE: Some multimeter range switches also select functions.

C. Connect test leads to proper test jacks.

D. Make necessary meter adjustments.

Example: Set "Ohms Zero Adjust" for a zero ohms reading with meter prepared for ohms measurement and leads connected to each other

NOTE: "Meter zero" and "zero ohms" readings are at opposite ends of the scale.

V. Procedures for measuring voltage (TM 2.3)

A. Position meter to correct function (-DC, +DC or AC)

B. Observing polarity, connect meter leads to meter.

C. Determine correct range and scale.

NOTE: If voltage is unknown, use the highest range. Connect voltmeter across the component or power source to be tested. Turn off power when installing or removing meter leads whenever possible.

D. Observing polarity, connect meter leads to circuit to be tested.

E. Set meter on lowest registering scale.

F. Read correct voltage.

G. Disconnect meter leads.

H. Turn off meter.

VI. Procedures for measuring amperage (TM 2.4)

A. Turn off power to circuit under test.

B. Position meter to correct scale.

C. Determine correct range.

NOTE: If amperage is unknown, use the highest scale.

D. Observing polarity, connect test leads to meter.

E. Connect meter in circuit to be tested, observing polarity and connecting in series with the circuit.

F. Turn on equipment under test.

G. Observe meter reading.

H. Position range switch to correct scale for most accurate reading.

I. Determine correct amperage reading.

J. Turn off power to equipment.

K. Disconnect meter.

L. Reconnect circuit.

M. Turn off meter.

VII. Procedures for measuring resistance (TM 2.5)

A. Turn off power to circuit under test.

WARNING: Be sure circuit is totally de-energized.

B. Position meter to the correct function position.

C. Position meter range switch to one of the resistance scales.

D. Insert meter leads in correct meter jacks, observing polarity.

E. Isolate component to be checked. (Disconnect one end of component.)

F. Connect meter across component to be measured.

G. Determine correct meter position closest to center or toward zero.

H. Perform zero ohms adjustment according to manufacturer's manual.

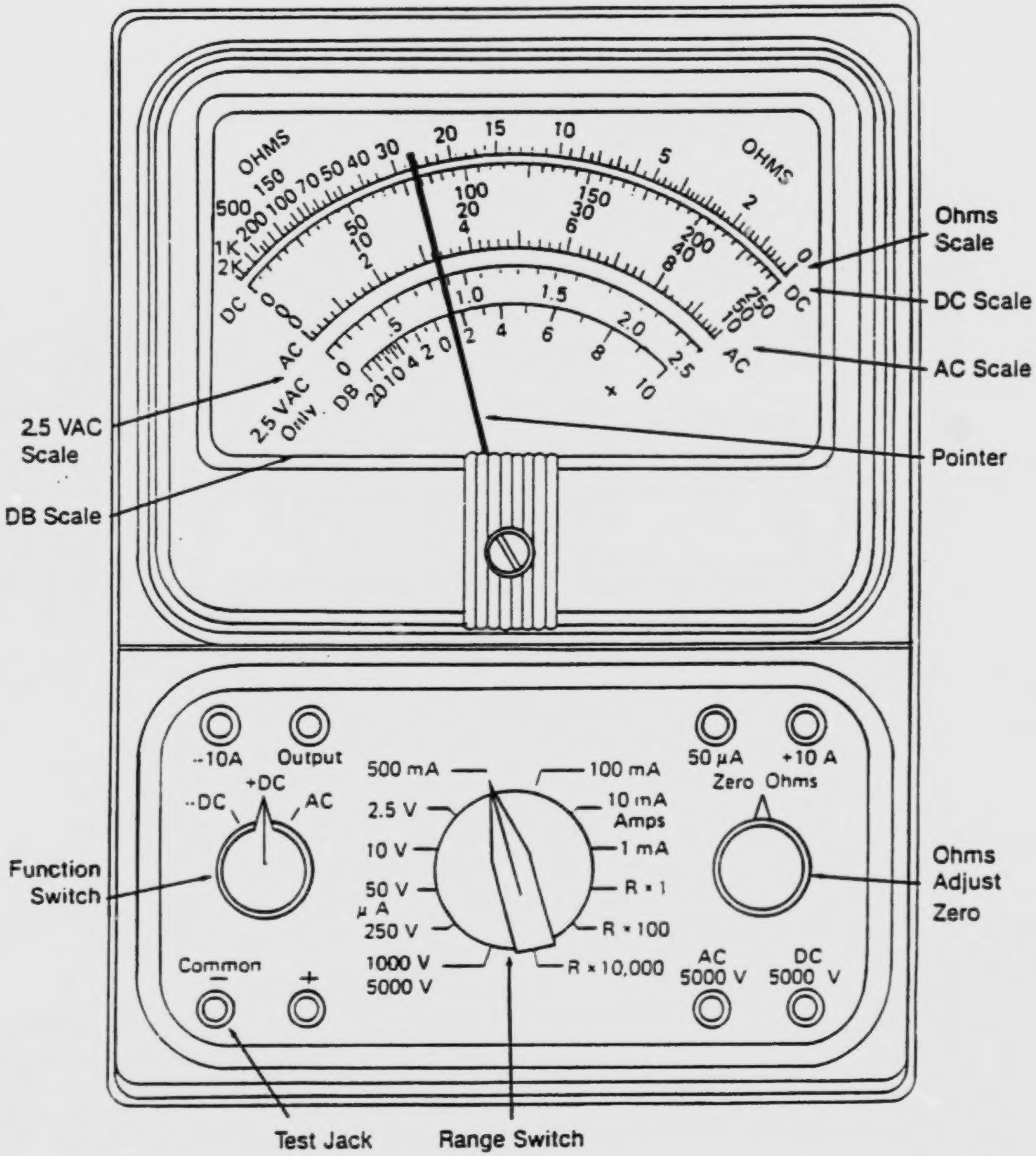
I. Reconnect meter to component.

- J. Read meter for ohmic value.
- K. Remove meter leads.
- L. Turn off meter.
- M. Reconnect component in circuit.

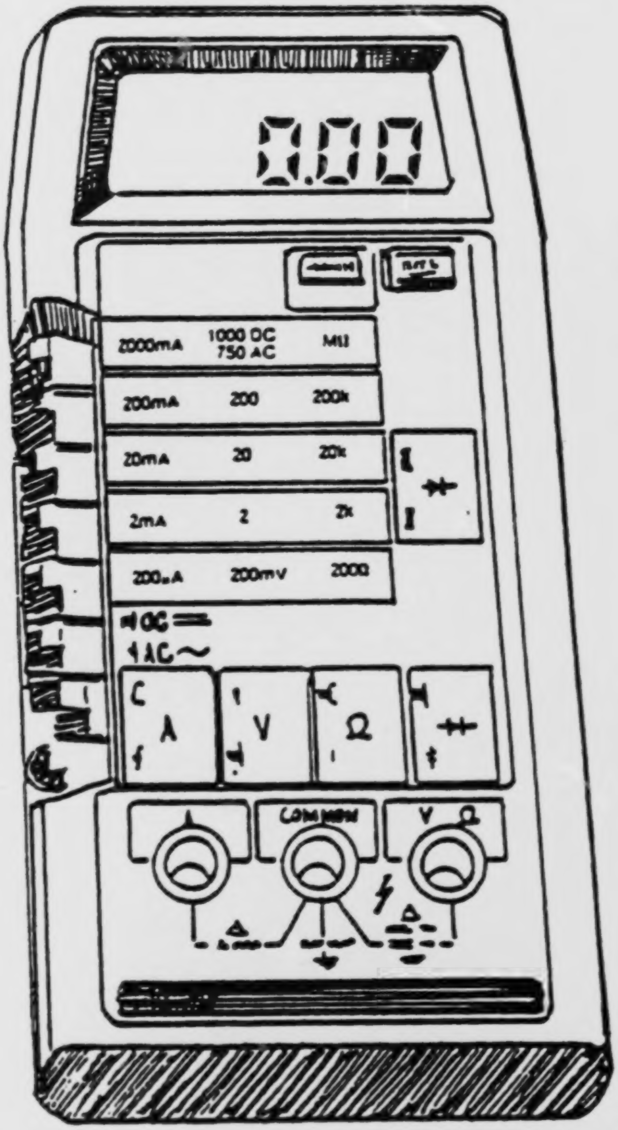
VIII. Measurement characteristics

- A. Amperage (directly in series) (TM 2.4)
  1. All current passes through the ammeter.
  2. Technique is limited to small measurements.
  3. Alternating current or direct current can be measured.
- B. Voltage (direct parallel measurement) (TM 2.3)
  1. Voltmeter probes connect directly across terminals.
  2. Techniques limited to moderate AC or DC voltages.
  3. When measuring AC voltages, the reading is in RMS (effective) voltage; lead polarity is not critical.
- C. Resistance
  1. Power must be removed from the circuit.
  2. Component should be isolated for true value measurement.

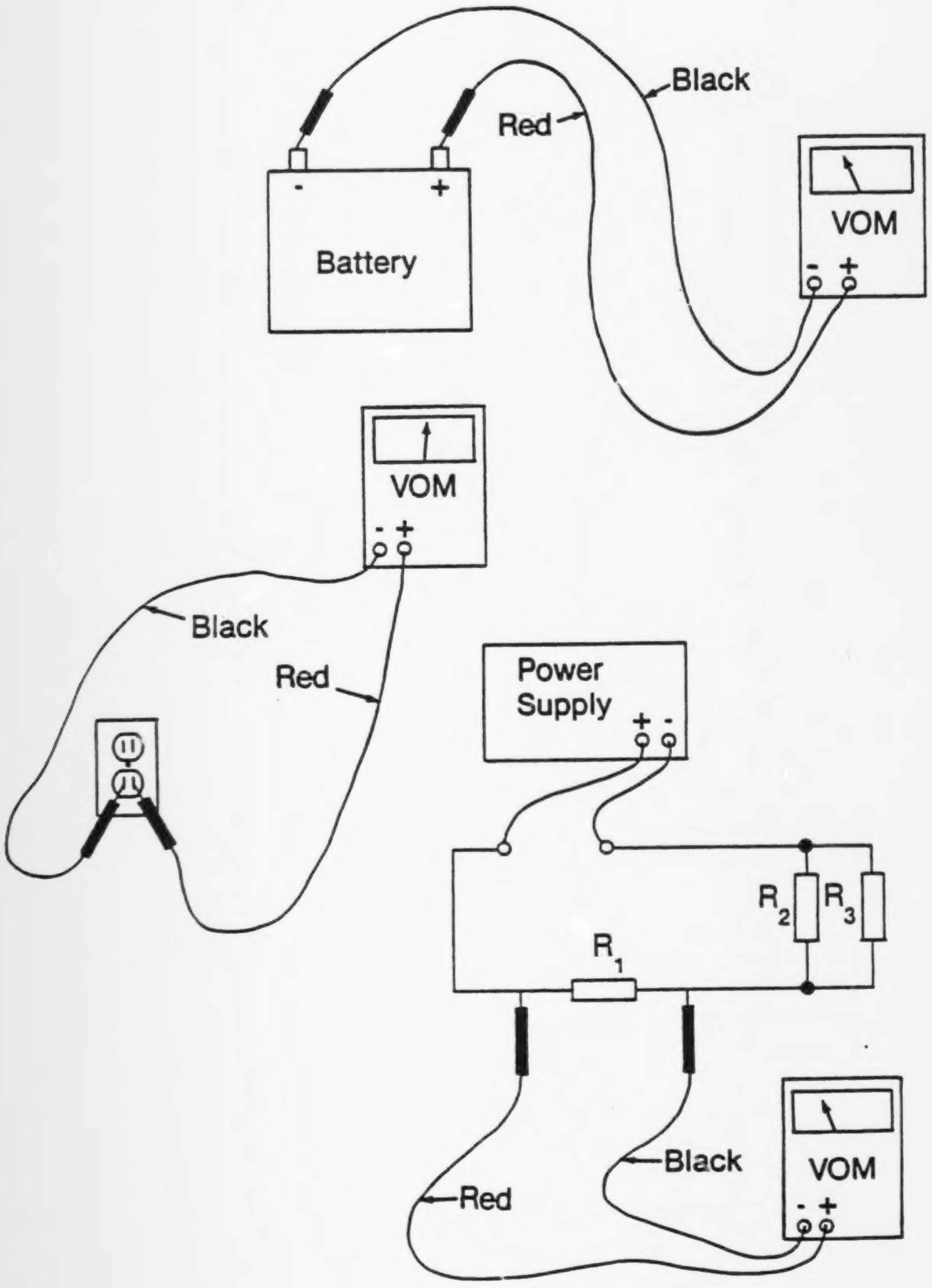
ANALOG MULTIMETER
(Simpson 260)


OHMS
500 150 200 100 70 50 40 30
1K
2K
20 15 10 5 2 0
100 20 4
150 30 6
200 40 8
250 50 10
50 10 2
DC
AC
1.0 1.5 2.0 2.5
0 .5
2 4 6 8 10
20 10 4 2 0
DB
2.5 VAC Only
Ohms Scale
DC Scale
AC Scale
2.5 VAC Scale
DB Scale
Pointer
-10A
Output
+DC
-DC
AC
Function Switch
Common
−
+
500 mA
2.5 V
10 V
50 V
µA
250 V
1000 V
5000 V
100 mA
10 mA
Amps
1 mA
R × 1
R × 100
R × 10,000
50 µA
+10 A
Zero Ohms
Ohms Adjust Zero
AC 5000 V
DC 5000 V
Test Jack
Range Switch

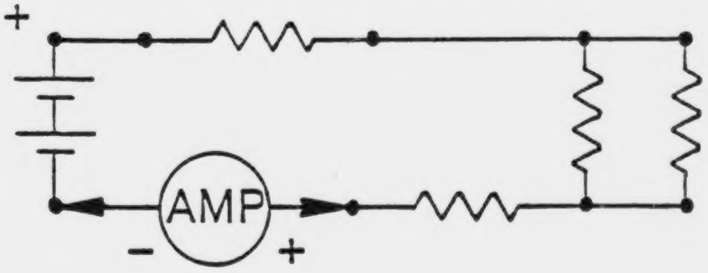
DIGITAL MULTIMETER


0.00
2000mA
1000 DC
750 AC
MΩ
200mA
200
200k
20mA
20
20k
2mA
2
2k
200µA
200mV
200Ω
DC
AC ~
A
V
Ω
COMMON
V Ω

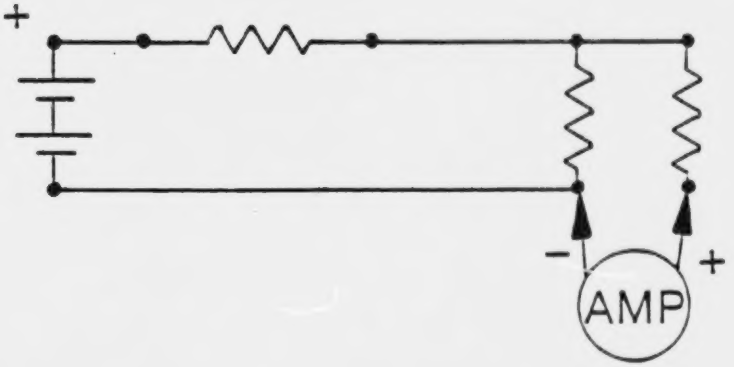
CORRECT VOLTAGE MEASUREMENTS


Black
Red
-
+
Battery
VOM
- +
VOM
- +
Black
Red
Power
Supply
+ -
R2
R3
R1
Black
Red
VOM
- +

CORRECT AMPERAGE MEASUREMENTS

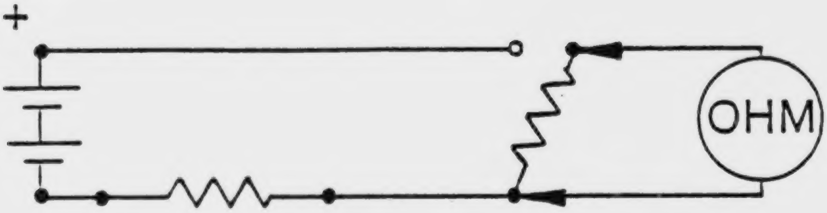


Measuring Amperage in Series Circuits

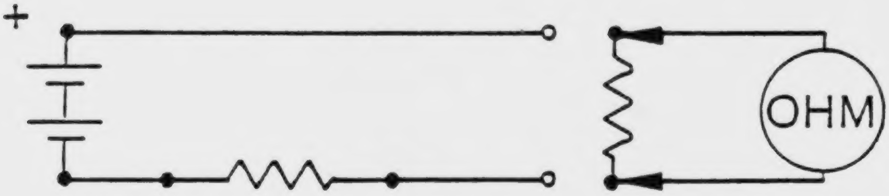


Measuring Amperage in Parallel Circuits

CORRECT RESISTANCE MEASUREMENTS



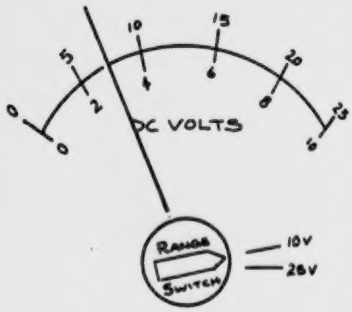
Isolating Component by Removing One Lead



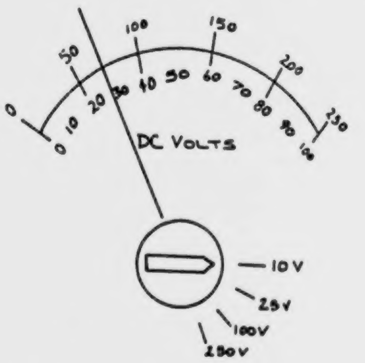
Isolating Component by Removing All Leads

READ ANALOG VOLTMETER AND AMMETER SCALES

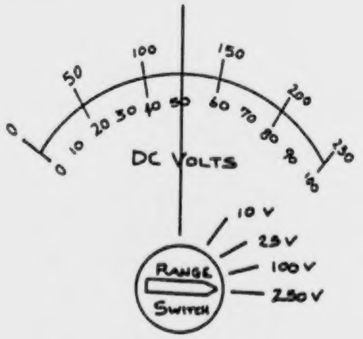
Record the voltage and analog readings indicated by the scales shown below.


0
5
10
15
20
25
0
2
4
6
8
10
DC VOLTS
RANGE
SWITCH
10V
25V

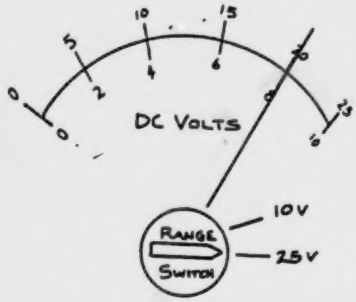
1. ________


0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100
DC VOLTS
10 V
25V
100V
250V

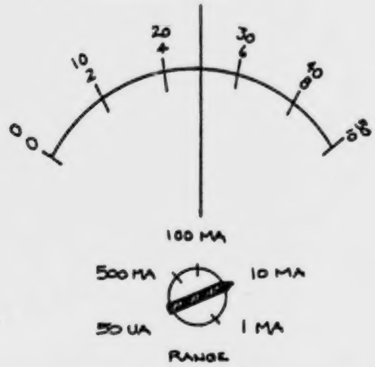
2. ________


0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100
DC VOLTS
10 V
25V
100V
250V
RANGE
SWITCH

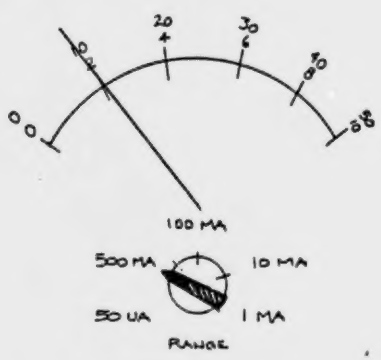
3. ________


0
5
10
15
20
25
0
2
4
6
8
10
DC VOLTS
RANGE
SWITCH
10V
25V

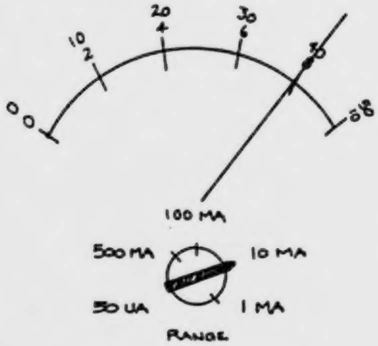
4. ________


0
10
20
30
40
50
0
2
4
6
8
10
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

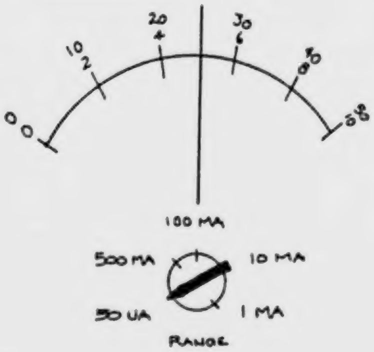
5. ________


0
10
20
30
40
50
0
2
4
6
8
10
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

6. ________

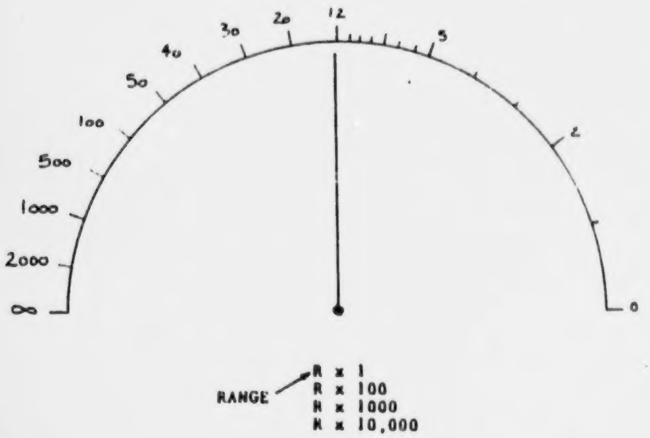

0
10
20
30
40
50
0
2
4
6
8
10
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

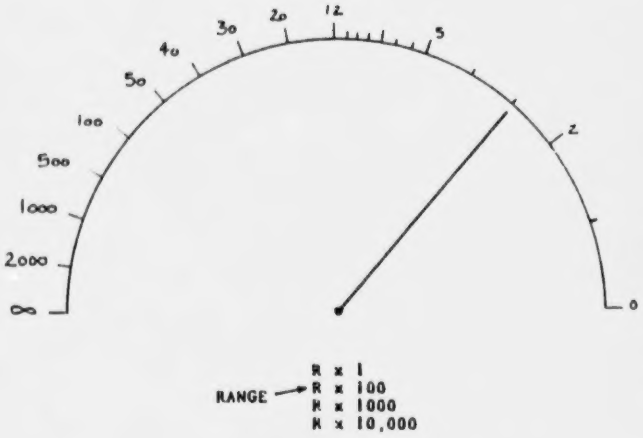
7. ________


0
10
20
30
40
50
0
2
4
6
8
10
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

8. ________

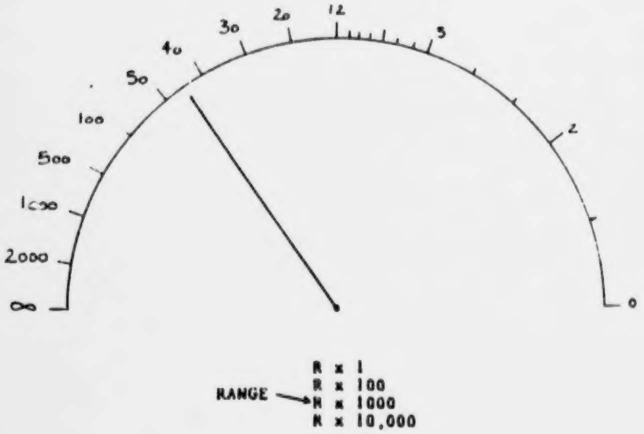
READ ANALOG OHMMETER SCALES

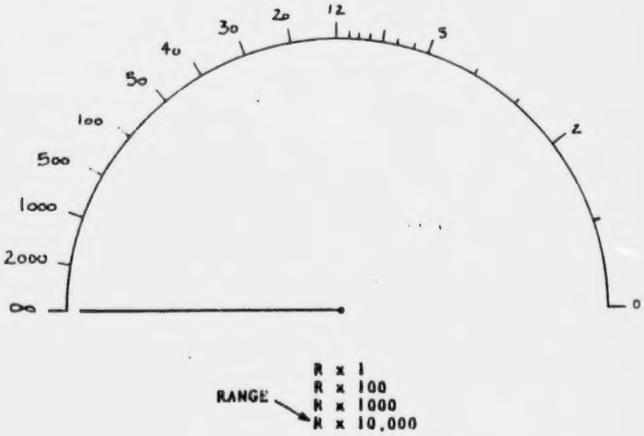

∞
2000
1000
500
100
50
40
30
20
12
5
2
0
RANGE
R x 1
R x 100
R x 1000
R x 10,000


∞
2000
1000
500
100
50
40
30
20
12
5
2
0
RANGE
R x 1
R x 100
R x 1000
R x 10,000

1. ________

2. ________


∞
2000
1000
500
100
50
40
30
20
12
5
2
0
RANGE
R x 1
R x 100
R x 1000
R x 10,000


∞
2000
1000
500
100
50
40
30
20
12
5
2
0
RANGE
R x 1
R x 100
R x 1000
R x 10,000

3. ________

4. ________

ANSWERS TO AS 2.1

1. 3V
2. 2.7V or 2.8V
3. 125V
4. 20V
5. 5mA
6. 100mA
7. 8mA
8. 25uA

ANSWERS TO AS 2.2

1. 1Ω
2. 300Ω
3. 45KΩ
4. Infinity

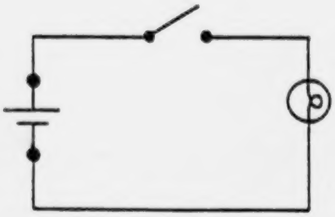
JS 2.1

MEASURE THE VOLTAGE DROP IN A DC CIRCUIT

Equipment:

Analog and digital voltmeters
1.5V cell and 9V battery (or adjustable power supply)
Lamp or load
Switch

Procedure:	Evaluation 3	 2	 1	 N
1. Connect the circuit as shown below. (Use the chart to the right of the illustration to record readings.)	___	___	___	___



Steps	1.5v (analog meter)	1.5v (digital meter)	9v (analog meter)	9v (digital meter)
2.				
3.				
4.				
5.				
6.				

	3	2	1	N
2. Close the switch. Connect the analog voltmeter across the power source (and adjust for 1.5V, if necessary). Read and record the voltmeter indication.	___	___	___	___
3. Connect the voltmeter across the lamp or load. Read and record the voltmeter indication.	___	___	___	___
4. With the switch still closed, measure and record voltage across the switch.	___	___	___	___
5. With the voltmeter still connected to the switch, open the switch. Read and record the voltmeter indication with the switch open.	___	___	___	___
6. With the switch open, read and record the voltmeter indication across the lamp.	___	___	___	___
7. Repeat steps 2-6 using the digital voltmeter.	___	___	___	___
8. Repeat all steps using a 9V power source. Record readings.	___	___	___	___
9. All blanks in the chart should now be filled. Return equipment and materials to the proper storage area.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average is the student's partial evaluation for competencies B12 and H2.

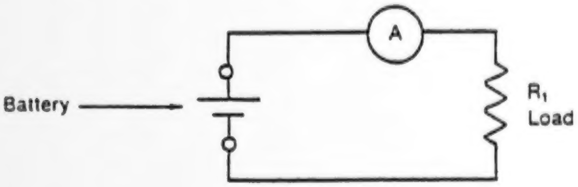
JS 2.2

MEASURE AND COMPARE CURRENT AT TWO DIFFERENT VOLTAGE LEVELS

Equipment:

DC ammeter (or multimeter)
Battery
Load (lamp or other resistance)

	Evaluation			
Procedure:	3	2	1	N
1. Connect the circuit as shown below; set DC power source at 1.5 vdc.	___	___	___	___



	3	2	1	N
2. Calculate and record the current in the circuit. ____________	___	___	___	___
3. Measure and record the current in the circuit amperage. ____________	___	___	___	___
4. Increase power source to 3 vdc. Calculate and record the current in the circuit. ____________	___	___	___	___
5. Measure and record the current. ____________	___	___	___	___
6. Compare current measurements to calculated values and current measurements at the different voltage settings.	___	___	___	___
7. Return equipment and materials to the proper storage area.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average is the student's partial evaluation for competencies B12 and H2.

MEASURE RESISTANCE WITH AN OHMMETER

Equipment:

Multimeter
Five assorted resistors
One lamp (light bulb)

NOTE: Steps of procedure may vary.

Procedure:

	Evaluation 3	2	1	N

1. Tape resistors to a sheet of notebook paper.
2. Connect the **ohmmeter** to each resistor and record the measured value in the table below.

Resistor	**Color code value**	**Measured value**	**Within tolerance? (Y/N)**
1			
2			
3			
4			
5			

3. Connect the ohmmeter to the lamp and record its value.
4. If **digital and analog multimeters** are available, switch to the other type and repeat steps 2 and 3 above.
5. Return tools and materials to proper storage area.

Average of above evaluations* — — — —

***This average is the student's final evaluation for competency H2: Describe the operation and demonstrate the use of multimeters; i.e., VOM, EVM or DVM, and partial evaluation for competency B12.**

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT V: USE OF MULTIMETERS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. What does a typical VOM measure?

a. Voltage
b. Current
c. Resistance
d. a and c
e. a, b and c

____ 2. The function of a multimeter refers to __________.

a. The number of leads it has
b. How high a reading it can make
c. Whether it is to be used on a series or parallel circuit
d. Its measurement of current, voltage or resistance
e. None of the above

____ 3. Parallax error is associated with which of the following?

a. Measuring voltage
b. Measuring resistance
c. Measuring current
d. Analog meters
e. Digital meters

____ 4. A multimeter has very high resistance when it measures which of the following?

a. Power
b. Current
c. Voltage
d. Resistance
e. All of the above

____ 5. Power to a circuit must be turned off when measuring which of the following?

a. Current
b. Resistance
c. Voltage
d. Power
e. None of the above

____ 6. What does a typical multimeter measure?

a. Current and voltage
b. Resistance and voltage
c. Resistance and current
d. Power, current and voltage
e. Current, voltage and resistance

___ 7. The range switch of a multimeter determines _________.

a. If it is to measure current, voltage or resistance
b. The maximum quantity the meter can measure
c. The polarity of what is to be measured
d. All of the above
e. None of the above

___ 8. When measuring resistance, which of the following is true?

a. The power source of the circuit must be disconnected
b. The meter must have an internal power source
c. Both meter leads must be used
d. All of the above
e. None of the above

___ 9. What results from improper polarity of meter probes?

a. Possible damage to an analog meter
b. Possible damage to a digital meter
c. No damage to either a digital or an analog meter
d. No harmful effects if used to measure current
e. No damage if used to measure voltage

___ 10. When are the leads of the multimeter connected in series?

a. After circuit power is disconnected
b. When used as an ohmmeter.
c. When used as a voltmeter
d. When used as a wattmeter
e. When used as an ammeter

___ 11. When read from left to right, which scale decreases in value?

a. Voltmeter scale
b. Ammeter scale
c. Ohmmeter scale
d. All of the above
e. None of the above

___ 12. Which of the following does a good ammeter have?

a. Very low resistance (high conductance)
b. Very high resistance (low conductance)
c. More than two leads to connect to the circuit
d. a and c above
e. b and c above

___ 13. A zero adjustment is made when the analog multimeter is used as _________.

a. An ammeter
b. A voltmeter
c. An ohmmeter
d. A wattmeter
e. None of the above

NOTE: Completion of this unit test to a specified score is the student's partial evaluation for competency B12: Identify and test resistors.

ANSWERS TO UNIT TEST

1. e
2. d
3. d
4. c
5. b
6. d
7. b
8. d
9. a
10. e
11. c
12. a
13. c

NOTE: Completion of this unit test to a specified score is the student's partial evaluation for competency B12: Identify and test resistors.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to determine the value of any circuit quantity through accurate circuit analysis. This knowledge will be evidenced by achieving a specified score on the unit test and job sheets.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Match terms with definitions.

1.2 Use the color code to find the resistance and tolerance of a resistor.

1.3 Interpret the power rating of a resistor.

1.4 Identify variable resistor characteristics. (partial B12)

2.1 Identify terms and definitions.

2.2 Analyze series circuits for all electrical quantities. (partial B15, JS 2.1 and JS 2.2)

2.3 Simplify a multiple-component series circuit into an equivalent circuit.

3.1 Match terms and definitions.

3.2 Determine current values in a parallel circuit. (partial B15, JS 3.1)

3.3 Determine resistance values in a parallel circuit. (partial B15, JS 3.2)

3.4 Determine voltage and power values in a parallel circuit. (partial B15, JS 3.2)

3.5 Simplify a multiple-component parallel circuit to an equivalent circuit.

4.1 Analyze and simplify compound circuits for all electrical quantities. (partial B15, JS 4.1 and 4.2)

5.1 Analyze voltage-divider circuits for all electrical quantities. (partial B15, JS 5.1)

5.2 Identify the effects of loaded voltage-divider circuits.

6.1 Match terms and definitions.

6.2 Identify bridge circuits and uses.

6.3 Distinguish between balanced and unbalanced bridge circuits by measuring voltages. (partial B15, JS 6.1)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: RESISTOR COLOR CODES
   a. Information outline
   b. Handout
      HO 1.1: Resistor color code for three-, four- and five-band resistors
   c. Assignment sheet
      AS 1.1: Resistor color codes
   d. Answers to assignment sheet
2. Lesson 2: SERIES CIRCUITS
   a. Information outline
   b. Transparency masters
      TM 2.1: Voltage drops in a resistive circuit
      TM 2.2: Current in a series circuit
   c. Assignment sheets
      AS 2.1: Total resistance
      AS 2.2: Total voltage
      AS 2.3: Voltage drops across resistances
      AS 2.4: Current
      AS 2.5: Power computations
      AS 2.6: Unknown circuit values
   d. Answers to assignment sheets
   e. Job sheets
      JS 2.1: Measure voltage drops
      JS 2.2: Analyze current values
3. Lesson 3: PARALLEL CIRCUITS
   a. Information outline

b. Transparency masters

TM 3.1: Parallel circuit

c. Handouts

HO 3.1: Current flow and current calculation
HO 3.2: Total resistance calculations and voltage

d. Assignment sheets

AS 3.1: Resistance
AS 3.2: Current and voltage
AS 3.3: Power
AS 3.4: Various values

e. Answers to assignment sheets

f. Job sheet

JS 3.1: Measure voltage, current and resistance
JS 3.2: Measure voltage, current and resistance using a power supply

4. Lesson 4: SERIES-PARALLEL CIRCUITS

a. Information outline

b. Handouts

HO 4.1: Series-parallel and equivalent circuits
HO 4.2: Circuit reduction
HO 4.3: Simplifying series-parallel

c. Assignment sheets

AS 4.1: Current flow
AS 4.2: Total resistance
AS 4.3: Total current and voltage
AS 4.4: Total power

d. Answers to assignment sheets

e. Job sheet

JS 4.1: Analyze a series-parallel circuit
JS 4.2: Analyze a series-parallel circuit

5. Lesson 5: VOLTAGE- AND CURRENT-DIVIDER CIRCUITS

a. Information outline

b. Transparency masters

TM 5.1: Voltage divider
TM 5.2: Loaded voltage divider

c. Assignment sheet

AS 5.1: Voltage divider

d. Answers to assignment sheet

e. Job sheet

JS 5.1: Construct and analyze a voltage divider

6. Lesson 6: BRIDGE CIRCUITS

a. Information outline

b. Transparency master

TM 6.1: Balanced bridge

c. Job sheets

JS 6.1: Measure voltages

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, N.Y.: Parker Publishing Co., Inc., 1981.

2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

3. Graf, Rudolf F. Modern Dictionary of Electronics. Indianapolis, Ind.: Howard W. Sams & Co., Inc., 1977.

4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

5. Schuler, Charles A.; Richard J. Fowler. Basic Electricity and Electronics. St. Louis: McGraw-Hill, 1988.

B. Curriculum guides

1. Hartman, Lonnie. Basic Electronics. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, 1987.

2. Robertson, L. Paul. Basic Electronics I. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, 1980.

3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. The first five lessons cover basic circuit analysis from color codes to compound circuits. These are included in every course of study, usually in this order.

2. Lesson 6 (bridge circuits) and Lesson 7 (network theorems) may be used in order, at other appropriate times as specific circuits relate to their use, or only in other parts of your program. This will depend upon how your course of study is developed.

B. Suggested supplemental materials

1. "Color code chart (for) fixed resistors" (part #597-1715). Benton Harbor, MI: Heathkit Educational Systems, 1978.

2. Bruce, David. Modern Electronic Basics, Devices and Applications. Reston, VA: Reston Publishing Co., Inc., Prentice-Hall, 1984.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

LESSON 1: RESISTOR COLOR CODES

NOTE: Most resistors indicate their nominal value by color code bands. The ability to interpret these colors is an important step in making efforts productive and efficient.

I. Terms and definitions

  A. Color code--method of placing specific values on components without placing numbers on the body of the component

  B. Digit--a single character in a number (e.g. the number 123 has three digits: 1, 2 and 3)

  C. Multiplier--color band that indicates the number of zeros to add to preceding digits in order to determine the resistor's exact value

  Examples: The decimal point is moved to the left one place when gold is the color of the multiplier band and two places when silver is the color of the multiplier band.

  D. Tolerance--amount of variance from the actual stated value of a resistor allowed by the manufacturer

II. Using the color code (HO 1.1)

  A. The first band is the one closest to the end without a double wide gap between it and the other bands.

  B. Three- or four-color band resistors (HO 1.1)

    1. The first band is the first digit.

    2. The second band is the second digit.

    3. The third band is the multiplier (number of zeros to add to the first three digits)

      a. If gold, multiply 0.1 times the first two digits.

      b. If silver, multiply 0.01 times the first two digits.

    4. The fourth band is the tolerance.

      a. No color band present (three-band resistor) = ±20%

      b. Silver = ±10%

      c. Gold = ±5%

  C. Five-color band resistors

    1. The first band is the first digit.

    2. The second band is the second digit.

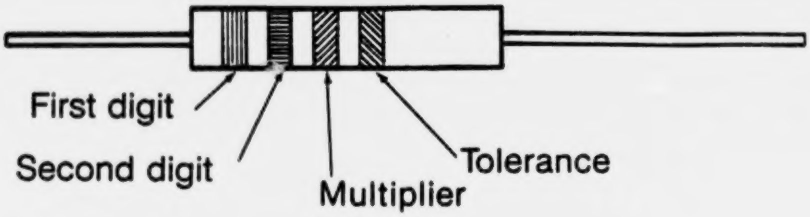
        3. The third band is the third digit.
        4. The fourth band is the multiplier.
            a. This is the number of zeros to add to the first three digits.
            b. If gold, multiply 0.1 times the first three digits.
            c. If silver, multiply 0.01 times the first three digits.
        5. The fifth band is the tolerance.
            a. Red = ±2%
            b. Brown = ±1%

III. Power ratings
    A. Color bands indicate only resistance, not power rating.
    B. A resistor's physical size indicates its ability to handle power (dissipate heat).
        1. Standard power ratings: 1/8, 1/4, 1/2, 1, 2, 5 and 10 watt
        2. Larger power ratings are available for special applications.

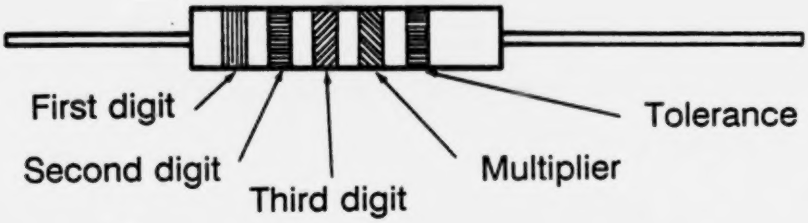
IV. Variable resistors
    A. Potentiometer, three terminal
    B. Rheostat, two terminal

HO 1.1

RESISTOR COLOR CODE FOR THREE-, FOUR- AND FIVE-BAND RESISTORS


First digit
Second digit
Multiplier
Tolerance

Color	1st digit	2nd digit	Multiplier	Tolerance
Black	0	0	1	±20%
Brown	1	1	10	±1%
Red	2	2	100	±2%
Orange	3	3	1000	---
Yellow	4	4	10000	---
Green	5	5	100000	---
Blue	6	6	1000000	---
Violet	7	7	10000000	---
Gray	8	8	---	---
White	9	9	---	---
Gold	---	---	0.1	±5%
Silver	---	---	0.01	±10%
No color	---	---	---	±20%

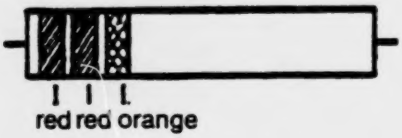

First digit
Second digit
Third digit
Multiplier
Tolerance

Color	1st digit	2nd digit	3rd digit	Multiplier	Tolerance
Black	0	0	0	1	
Brown	1	1	1	10	±1%
Red	2	2	2	100	±2%
Orange	3	3	3	1000	---
Yellow	4	4	4	10000	---
Green	5	5	5	100000	---
Blue	6	6	6	1000000	---
Violet	7	7	7	10000000	---
Gray	8	8	8	---	---
White	9	9	9	---	---
Gold	---	---	---	0.1	
Silver	---	---	---	0.01	
No color	---	---	---	---	

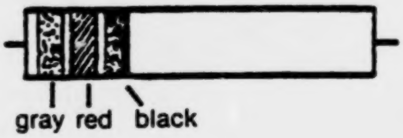
RESISTOR COLOR CODES

Compute the value of the following resistors using proper engineering notation. (Always use the unit symbol, Ω.)

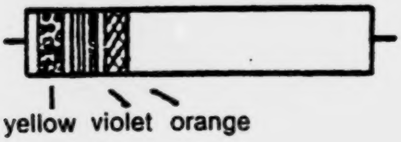
1. ___


red
red
orange

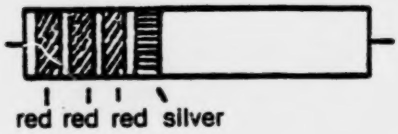
2. ___


gray
red
black

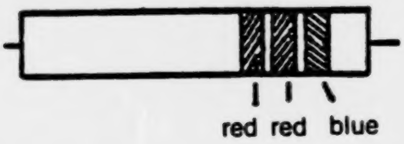
3. ___


yellow
violet
orange

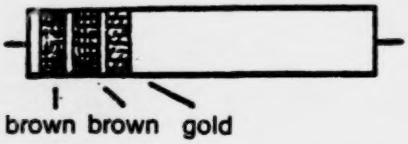
4. ___


red
red
red
silver

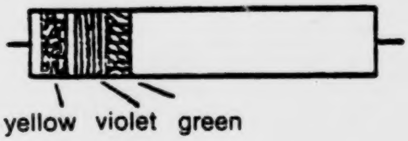
5. ___


red
red
blue

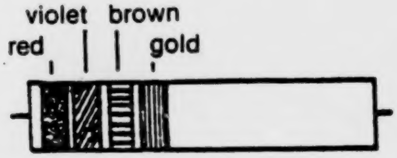
6. ___


brown
brown
gold

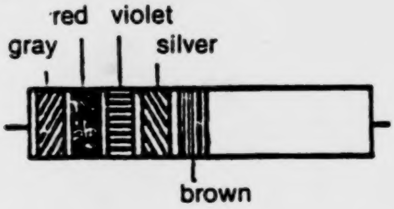
7. ___


yellow
violet
green

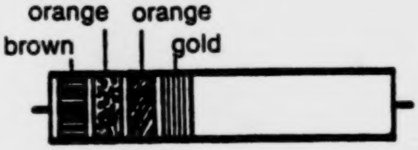
8. ___ (tolerance + ____ %)


violet
brown
red
gold

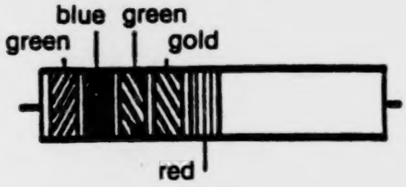
9. ___ (tolerance + ____ %)


red
violet
gray
silver
brown

10. ___ (tolerance + ____ %)


orange
orange
brown
gold

11. ___ (tolerance + ____ %)


blue
green
green
gold
red

12. The minimum value that resistor #4 would be expected to have is ________ ; the maximum expected value is ________ (assuming that it is within tolerance).

Match the following.

____ 13. Two-lead variable

____ 14. Three-lead variable

____ 15. Two-lead fixed

a. Resistor

b. Rheostat

c. Potentiometer

ANSWERS TO ASSIGNMENT SHEET 1.1

1. 22KΩ
2. 82Ω
3. 47KΩ
4. 2.2KΩ
5. 6.2KΩ
6. 1.1Ω
7. 4.7MΩ
8. 270Ω, ±5%
9. 8.27Ω, ±1%
10. 13KΩ, ±5%
11. 56.5Ω, ±2%
12. 256.5Ω, 283.5Ω
13. b
14. c
15. a

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

LESSON 2: SERIES CIRCUITS

I. Terms and definitions

A. Chassis ground--a common return circuit with a voltage that is not necessarily the same as earth ground

B. Closed circuit--circuit that has a complete and unbroken path for the flow of current

C. Ground--common return path with a voltage of zero compared to earth ground

D. Load--device designed to be supplied with electrical energy

E. Open circuit--a circuit's path that has been opened, stopping the flow of current

F. Series circuit--circuit that contains only one path for current

G. Voltage drop--loss of electrical force (voltage) in a component; observed by measuring the voltage across that component

H. Kirchhoff's voltage law--The sum of the voltages across the components of a series circuit must equal the voltage applied to the circuit.

II. Characteristics of current, voltage, power and resistance

A. In a series circuit, the sum of the resistances equals the total resistance (R) of the circuit.

NOTE: This can be expressed as $R_T = R_1 + R_2 + R_3 + \dots$

B. Kirchhoff's voltage law--The algebraic sum of all voltage drops and rises in a closed loop (series circuit) is equal to zero. Stated simply, the sum of voltage drops is equal to the applied voltage.

NOTE: This can be expressed as $V_T = V_1 + V_2 + V_3 + \dots$

1. The voltage drop across each individual resistor can be found by multiplying the resistance by the current through it ($E = I \times R$). (TM 2.1)

   NOTE: The voltage drop will be directly proportional to the value of the resistance. (The larger the R, the larger the E.)

2. For multiple-source circuits, voltages connected in a series-aiding configuration (the same polarities) can be added for a total equivalent voltage. Those in a series-opposing configuration (opposite polarities) can be subtracted for an equivalent voltage.

C. Current (I) is the same at all points in a series circuit (TM 2.2).

D. Total power dissipated in a series-resistive circuit is the same as the total power supplied by the source and can be found by totaling the powers dissipated by the resistors.

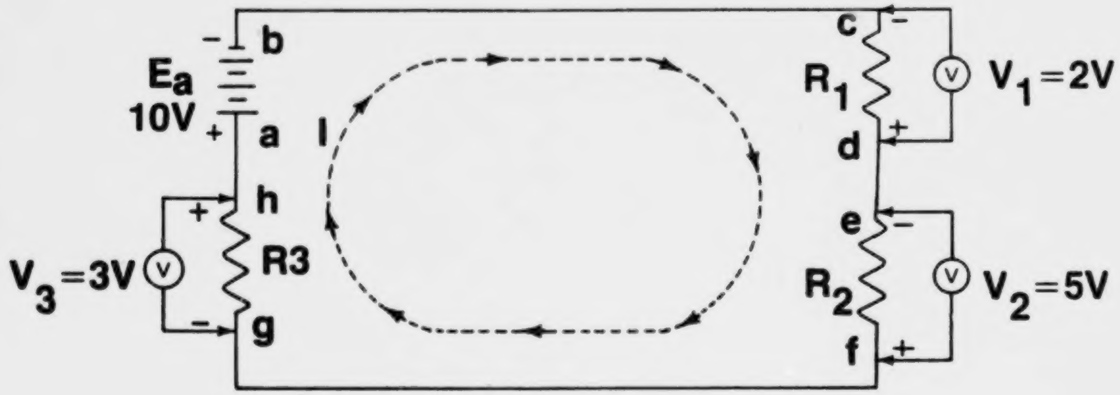
NOTE: This can be expressed as $P_T = P_1 + P_2 + P_3 + \dots$

III. Series-circuit equivalents

   A. Determine total circuit resistance (R_T).

   B. Redraw the circuit using only R_T as the load.

VOLTAGE DROPS IN A RESISTIVE CIRCUIT


–
b
E_a
10V
+
a
I
h
+
V_3=3V
R3
–
g
c
–
R_1
V_1=2V
+
d
e
–
R_2
V_2=5V
f
+

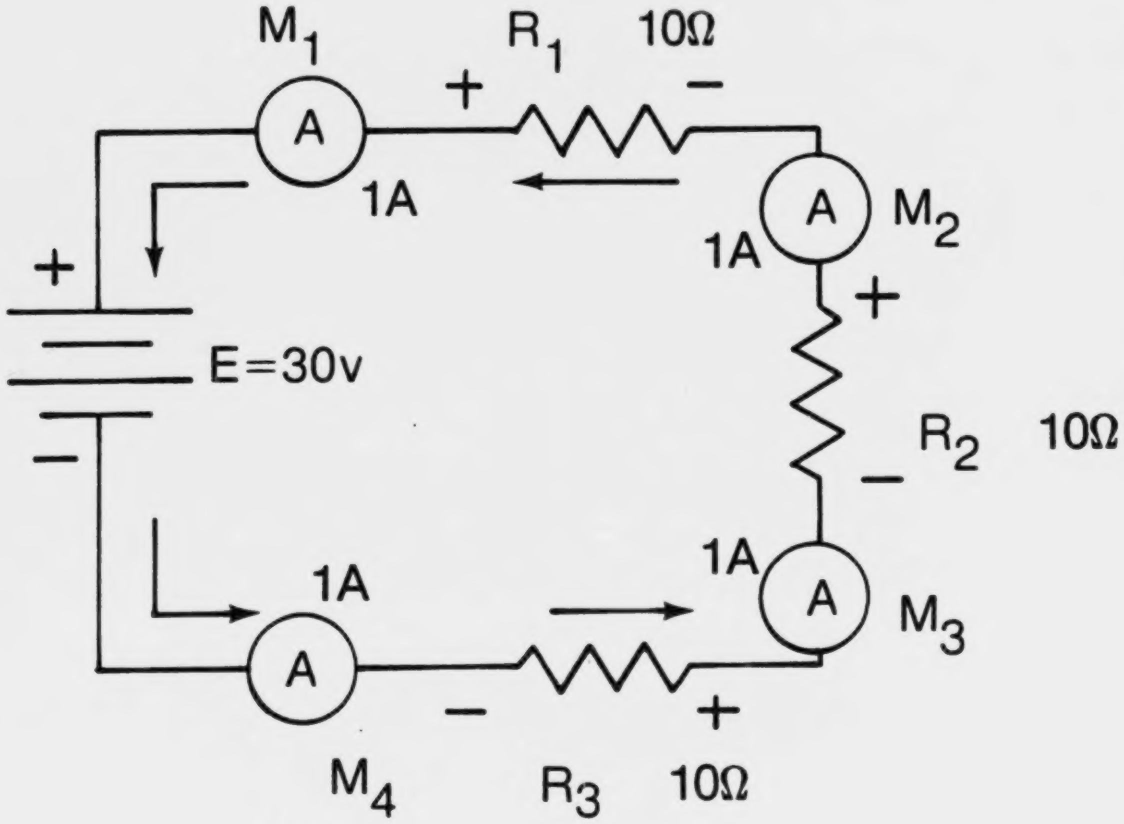
Applied voltage (E) = 10V

Direction of electron flow: Negative (b) to positive (a)

Application of Kirchhoff's Law of Voltage:

$V_1 + V_2 + V_3 = E_a$
$2V + 5V = 3V = 10V$

CURRENT IN A SERIES CIRCUIT


M1
R1
10Ω
+
−
A
1A
A
M2
1A
+
E=30v
+
−
R2
10Ω
−
1A
A
M3
1A
A
−
+
M4
R3
10Ω

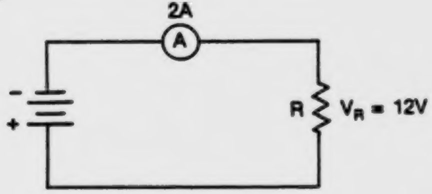
Current measured by M_1 will equal that of M_2, M_3 or M_4.

138

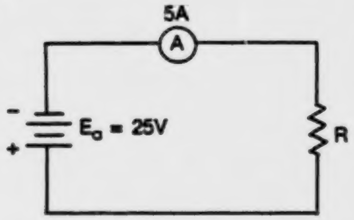
TOTAL RESISTANCE

Determine the total resistance in the following series circuits.

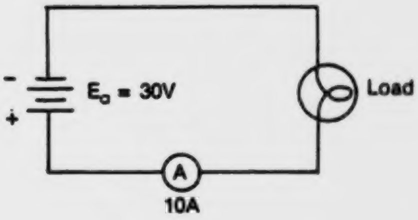
1. R_T = ____________________



2. R_T = ____________________



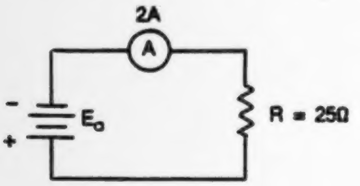
3. R_T = ____________________


-
+
E_o = 30V
Load
A
10A

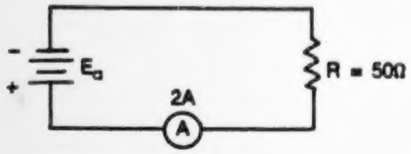
TOTAL VOLTAGE

Determine the total voltage in the following series circuits.

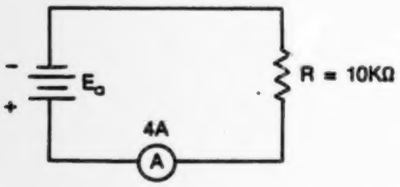
1. E_a = ______________



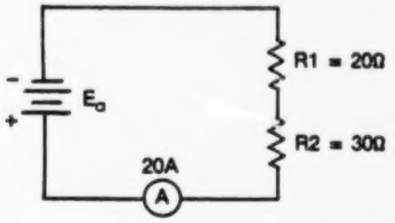
2. E_a = ______________



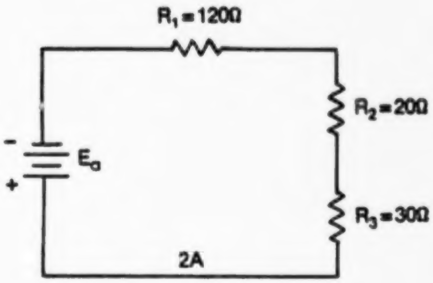
3. E_a = ______________


-
+
E_o
R = 10KΩ
4A
A

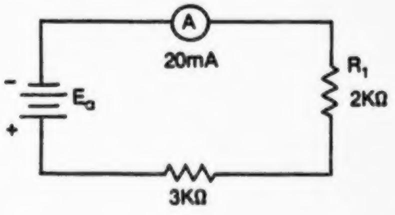
4. E_a = ______________


R1 = 20Ω
-
+
E_o
R2 = 30Ω
20A
A

5. E_a = ______________


R_1 = 120Ω
R_2 = 20Ω
-
+
E_o
R_3 = 30Ω
2A

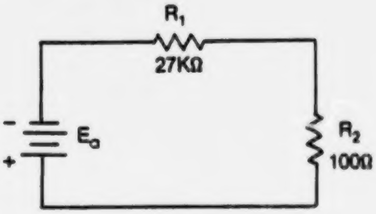
6. E_a = ______________


A
20mA
R_1
2KΩ
-
+
E_o
3KΩ

VOLTAGE DROPS ACROSS RESISTANCES

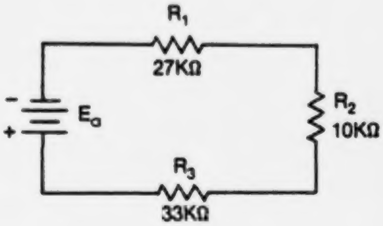
Determine voltage drops across resistances in the following series circuits.

____ 1. True or false? V_{R1} is greater than V_{R2}.

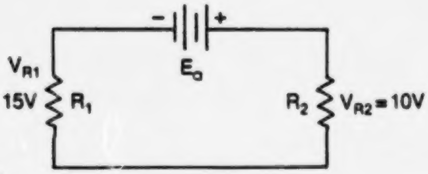

R1
27KΩ
-
+
Eₐ
R2
100Ω

____ 2. The largest voltage drop is __________.

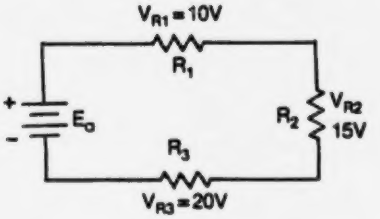
- a. V_{R1}
- b. V_{R2}
- c. V_{R3}


R1
27KΩ
-
+
Eₐ
R2
10KΩ
R3
33KΩ

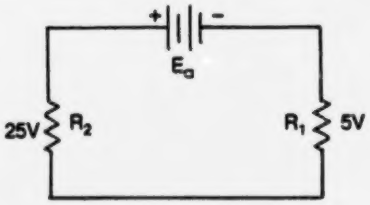
3. E_a = __________


-
+
Eₐ
VR1
15V
R1
R2
VR2 = 10V

4. E_a = __________


VR1 = 10V
R1
+
-
Eₐ
R2
VR2
15V
R3
VR3 = 20V

5. E_a = __________


+
-
Eₐ
25V
R2
R1
5V

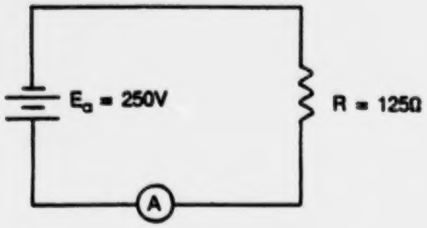
6. Simplify the circuit in question #1 by redrawing, including the equivalent circuit(s).

7. Simplify the circuit in question #2 by redrawing, including the equivalent circuit(s).

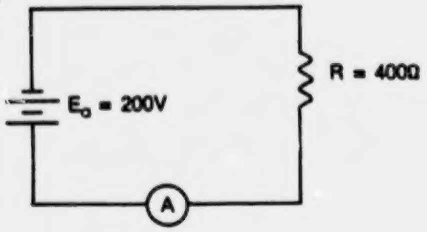
CURRENT

Determine the current in the following series circuits. Be sure to indicate units.

1. I = ____________

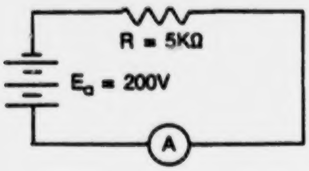

E_a = 250V
R = 125Ω
A

2. I = ____________


R = 400Ω
E_a = 200V
A

3. I = ____________

NOTE: Give answer in milliamperes.


R = 5KΩ
E_a = 200V
A

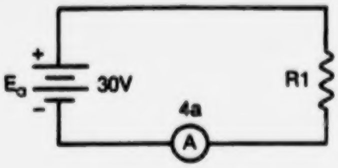
AS 2.5

POWER COMPUTATIONS

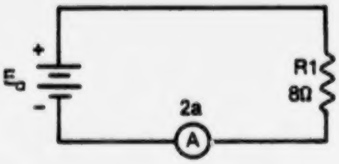
Study the following schematics and answer the questions below them. Use these formulas for power:

a. $P = EI$ when current and voltage are known
b. $P = I^2R$ when current and resistance are known
c. $P = E^2 + R$ when voltage and resistance are known

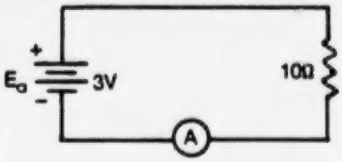
1. Which formula is needed to solve for power? _______ P = _____



2. Which formula is needed to solve for power? _______ P = _______



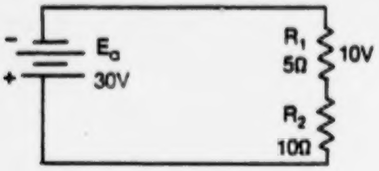
3. Which formula is needed to solve for power? _______ P = _______



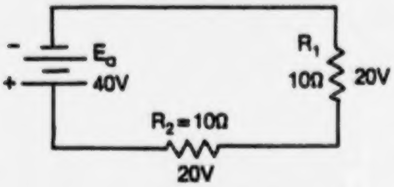
UNKNOWN CIRCUIT VALUES

Study the following schematics and determine unknown circuit values.

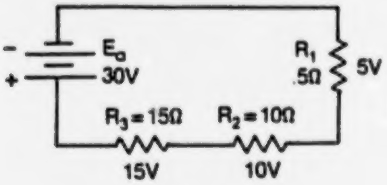
1. I_{R1} = ________


-
+
E_a
30V
R_1
5Ω
10V
R_2
10Ω

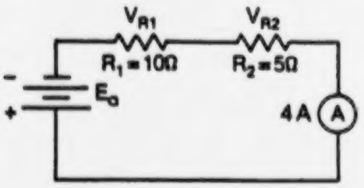
2. I_{R2} = ________


-
+
E_a
40V
R_1
10Ω
20V
R_2=10Ω
20V

3. IR_3 = ________

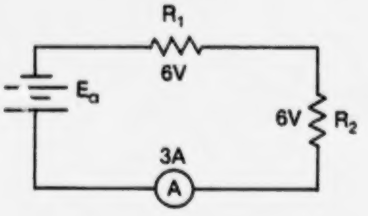

-
+
E_a
30V
R_1
.5Ω
5V
R_3=15Ω
R_2=10Ω
15V
10V

4. V_{R2} = ________

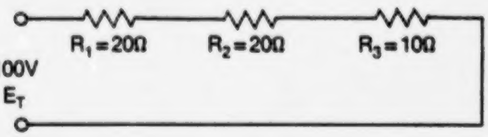

V_{R1}
V_{R2}
R_1=10Ω
R_2=5Ω
-
+
E_a
4A
A

NOTE: The Ohm's law formula applies to all parts of a circuit.

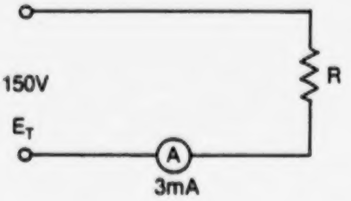
5. R_2 = ________


R_1
6V
E_a
6V
R_2
3A
A

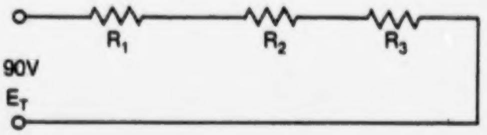
6. V_3 = ________


R_1=20Ω
R_2=20Ω
R_3=10Ω
100V
E_T

7. R = ________


150V
E_T
R
A
3mA

8. V_1 = ________


R_1
R_2
R_3
90V
E_T

NOTE: All resistors are equal in value. E_a represents the battery voltage. E_T is the total voltage from a source.

ANSWERS TO ASSIGNMENT SHEET 2.1

1. 6Ω
2. 5Ω
3. 3Ω

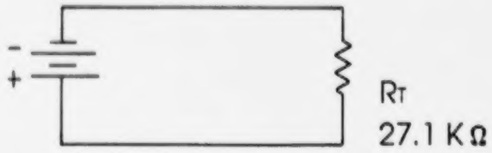
ANSWERS TO AS 2.2

1. 50V
2. 100V
3. 40,000V or 40KV
4. 1,000V or 1KV
5. 340V
6. 100V

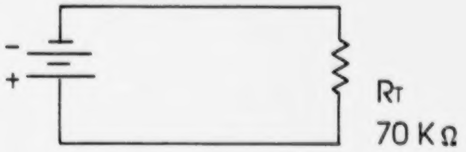
ANSWERS TO AS 2.3

1. True
2. C
3. 25V
4. 45V
5. 30V

6.



7.



ANSWERS TO AS 2.4

1. 2A
2. 500mA or 0.5A
3. 40mA

ANSWERS TO AS 2.5

1. a, 120 watts
2. b, 32 watts
3. c, 0.9 watts

ANSWERS TO AS 2.6

1. 2A
2. 2A
3. 1A
4. 20V
5. 2Ω
6. 20V
7. 50KΩ or 50,000Ω
8. 30V

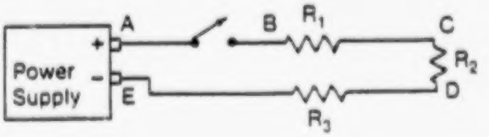
MEASURE VOLTAGE DROPS

Equipment:

Power supply
Switch (SPST)
Two resistors of the same value
One resistor of a different value
Voltmeter (or multimeter)

NOTE: The instructor will supply the value of voltage and resistors to use.

Procedure:	Evaluation 3	2	1	N
1. Connect the circuit according to the following schematic.	—	—	—	—



2. Close the switch.	—	—	—	—
3. Use the voltmeter to read and record the following:	—	—	—	—

E_a = ____________

V_{R1} = ____________

V_{R2} = ____________

V_{R3} = ____________

4. Add voltage drops across the three resistors and compare the sum with the amount of applied voltage. NOTE: Is Kirchhoff's law confirmed by the results? (yes/no)	—	—	—	—
5. Discuss how applied voltage distributes itself across resistances of unequal or of equal value.	—	—	—	—
6. Circle the most negative point in the circuit.				
7. As directed by instructor, advance to next job sheet or return equipment and materials to their proper storage location.	—	—	—	—
Average of above evaluation*	—	—	—	—

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

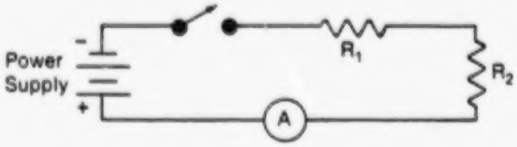
JS 2.2

ANALYZE CURRENT VALUES

Equipment:

Power supply
Switch (SPST)
Two resistors: R_1 = 4.7K, 1/8 watt (minimum); R_2 = 1K, 1W
Ammeter (or multimeter)
Voltmeter
Ohmmeter

Procedure:	Evaluation 3	2	1	N
1. Measure and record the ohms values of the resistors. ________	___	___	___	___
2. Connect a circuit as shown in the following schematic.	___	___	___	___



3. Close the switch and adjust the power supply output per instructor.	___	___	___	___
4. Use the voltmeter to measure the following voltages: V_{R1} = ________ V_{R2} = ________ E_a = ________	___	___	___	___
5. Read and record the ammeter indication. I = _____	___	___	___	___
6. Disconnect the circuit by opening the switch.	___	___	___	___
7. Use Ohm's law to compute: I_{R1} = ________ I_{R2} = ________ I_T = ________	___	___	___	___
8. Compare the values of the various current computations. Explain differences, if any, in these values.	___	___	___	___
9. Return equipment and materials to their proper storage area.	___	___	___	___
Average of above evaluation*	___	___	___	___

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

LESSON 3: PARALLEL CIRCUITS

I. Terms and definitions

   A. Branch--one of several current paths available to conduct current

   B. Kirchhoff's current law--The total amount of current entering a connection of three or more conductors (node) must equal the total amount of current leaving the connection.

   C. Node (junction)--connection of three or more conductors where currents can either split or join

II. Characteristics of current in a parallel circuit (TM 3.1)

   A. Current in a parallel circuit follows Kirchhoff's current law. (HO 3.1)

      NOTE: This also means that the sum of the individual branch currents can be added to obtain the value of total current in a parallel circuit. ($I_T = I_1 + I_2 + I_3 + \ldots$)

   B. Only a portion of the total circuit current flows through an individual branch.

   C. The current of each branch is equal to the voltage divided by the resistance of that branch, $I = E + R$.

   D. Total circuit current equals the sum of the individual branch currents ($I_T = I_1 + I_2 + I_3 + \ldots$).

   E. Total current can also be found by dividing the applied voltage by the total resistance ($I = E + R$).

   F. When branch resistance decreases, current in the branch increases; when resistance increases, current decreases.

III. Characteristics of resistance in a parallel circuit (HO 3.2)

   A. Total resistance of a parallel circuit is always less than the resistance of any individual branch.

   B. The reciprocal of the total resistance equals the sum of the reciprocals of the parallel resistances. (Conductance Method)

$$R_T = \frac{1}{(1 + R_1) + (1 + R_2) + (1 + R_3) \ldots}$$

      or $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 \ldots$

C. When the resistances of the individual branches are all equal, the total resistance is equal to the value of one of the branch resistors divided by the number of branches. (Equal Resistors Method)

$$R_T = \frac{\text{R (of individual branch)}}{\text{N (number of branches)}}$$

D. The total of two unequal resistances in parallel can be found by the formula below. (Product Over Sum Method)

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

E. When total current is known, total resistance can be found by dividing the applied voltage by the total current ($R = E \div I$). (HO 3.2)

IV. Characteristics of voltage and power in a parallel circuit

A. Voltage across each branch of a parallel circuit is the same.

Example: Christmas tree lights: The whole string of lights does not go out when one bulb burns out.

B. The voltage across each branch of a parallel circuit is equal to the source voltage.

C. Total power in a parallel circuit is the total power generated by the source and can be found by adding the individual values of power dissipated in the branches, i.e., $P_T = P_1 + P_2 + P_3 + \ldots$.

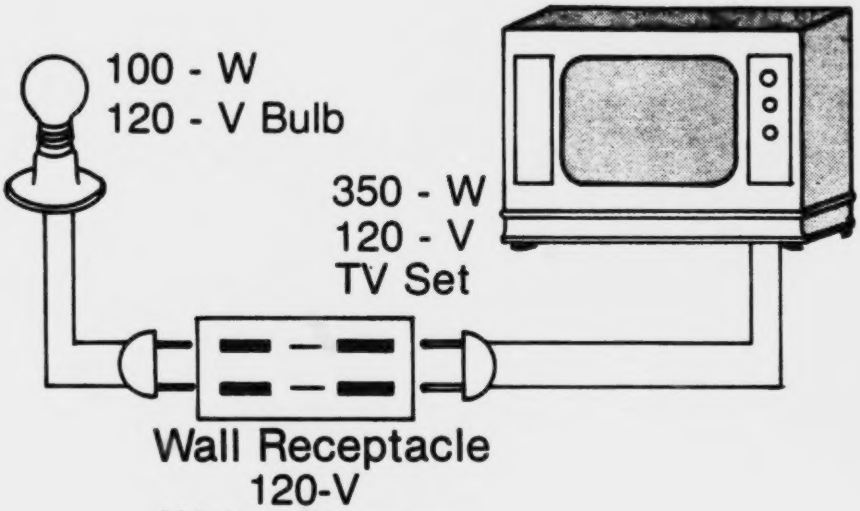
NOTE: Power in both series and parallel circuits is equal to the power delivered by the source.

V. Simplification of a parallel circuit

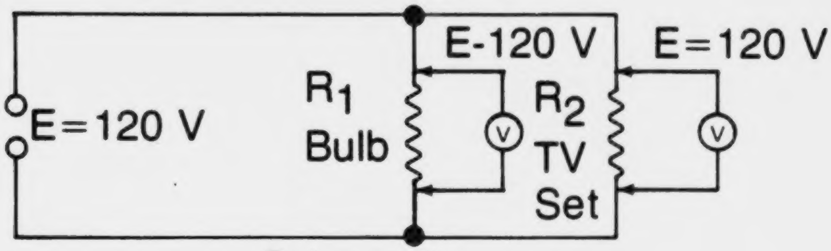
A. Determine total circuit resistance.

B. Redraw the circuit using only R_T as the load.

PARALLEL CIRCUIT


100 - W
120 - V Bulb
350 - W
120 - V
TV Set
Wall Receptacle
120-V

Wiring Diagram


E=120 V
R1
Bulb
E-120 V
R2
TV
Set
E=120 V
V
V

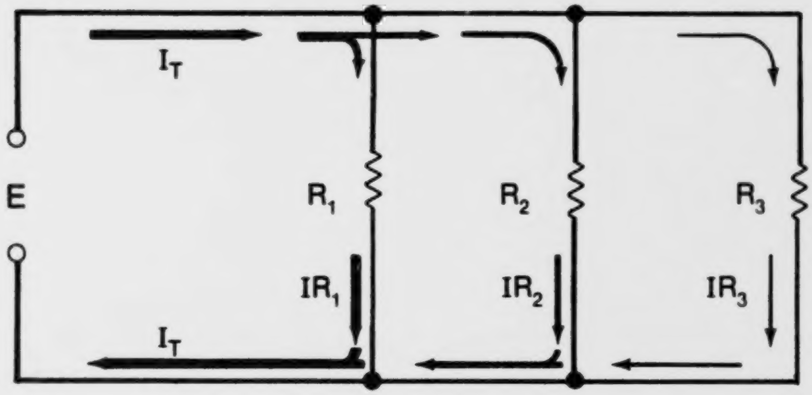
Schematic

This circuit provides two paths for current flow: through R_1 (bulb) and through R_2 (TV set).

Note that the voltage across both the bulb and the TV set is the same as the applied voltage (120V).

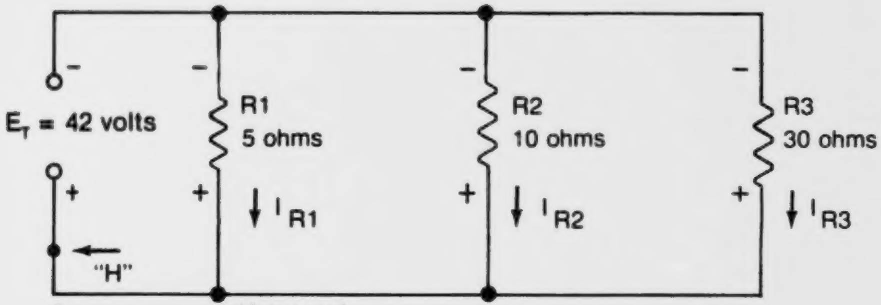
CURRENT FLOW AND CURRENT CALCULATION

(Kirchhoff's Current Law)


I_T
E
R_1
R_2
R_3
IR_1
IR_2
IR_3
I_T

The total current flowing through a parallel circuit is the sum of the currents flowing through each branch.

In the above circuit: $I_T = I_{R1} + I_{R2} + I_{R3}$

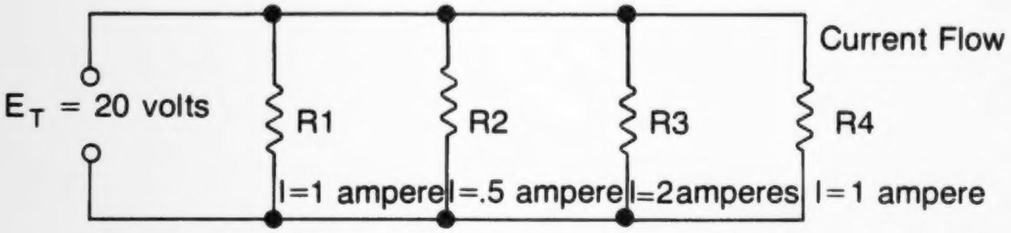

E_T = 42 volts
R1
5 ohms
R2
10 ohms
R3
30 ohms
I_{R1}
I_{R2}
I_{R3}
"H"
–
+

I_T =__________(Amperes)

How much current is passing through point "H" in this circuit? There are two methods for determining total current in this circuit:

1. Find the current flowing through each branch (ex.: $I_{R1}\ \frac{E}{R1}$), then add all 3 branch currents ($I_T = I_{R1} + I_{R2} + I_{R3}$).
2. Find the total resistance using the reciprocal resistance formula, then calculate total current ($I_T = \frac{E}{R_T}$).

TOTAL RESISTANCE CALCULATIONS AND VOLTAGE


Current Flow
E_T = 20 volts
R1
R2
R3
R4
I=1 ampere
I=.5 ampere
I=2amperes
I=1 ampere

$$R_T = \frac{E_T}{I_T} = \frac{E_T}{I_T} = 4.4 \text{ ohms}$$

$$R1 = \frac{20 \text{ volts}}{1 \text{ ampere}} = 20 \text{ ohms}$$

$$R2 = \frac{20 \text{ volts}}{.5 \text{ ampere}} = 40 \text{ ohms}$$

$$R3 = \frac{20 \text{ volts}}{2 \text{ amperes}} = 10 \text{ ohms}$$

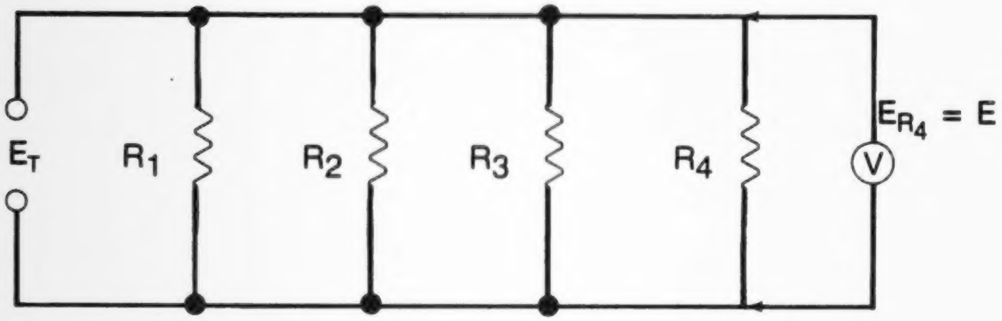
$$R4 = \frac{20 \text{ volts}}{1 \text{ ampere}} = 20 \text{ ohms}$$

$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4}$$

$$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{40} + \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{R_T} = \frac{2 + 1 + 4 + 2}{40} = \frac{9}{40}$$

$$R_T = \frac{40}{9} = 4.4 \text{ ohms}$$


E_T
R_1
R_2
R_3
R_4
V
E_R4 = E

The voltage across each branch of a parallel circuit is the same value.

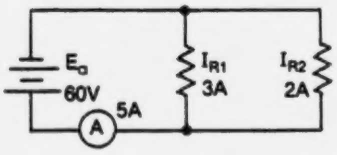
or

$$E_T = E_{R_1} = E_{R_2} = E_{R_3} = \ldots$$

RESISTANCE

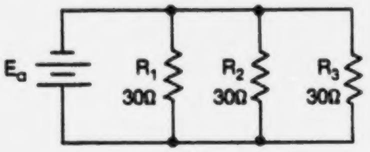
Calculate the following quantities.

1. R_1 ________
2. R_2 ________
3. R_T ________
4. $\frac{E_T}{I_T}$ = ____



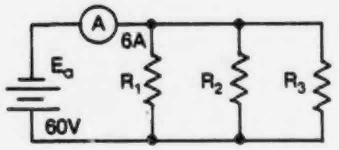
E_a
60V
5A
A
I_{R1}
3A
I_{R2}
2A

5. Calculate R_T. ________



E_a
R_1
30Ω
R_2
30Ω
R_3
30Ω

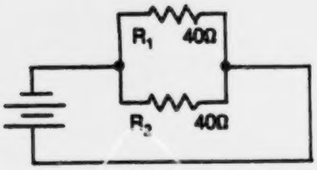
6. Calculate R_T. ______



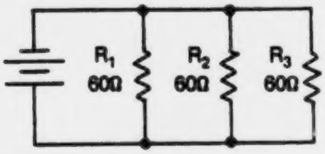
A
6A
E_a
60V
R_1
R_2
R_3

If the three resistors are equal in value, R_1 = ______ ohms.

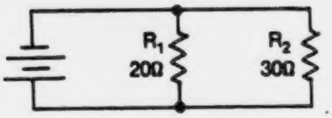
7. Calculate R_T. ________


R_1 40Ω
R_2 40Ω

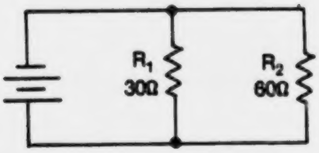
8. Calculate R_T. ________


R_1 60Ω
R_2 60Ω
R_3 60Ω

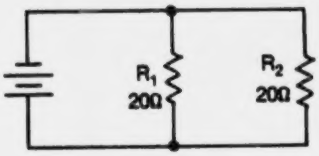
9. Calculate R_T. ________


R_1 20Ω
R_2 30Ω

10. Calculate R_T. ________


R_1 30Ω
R_2 60Ω

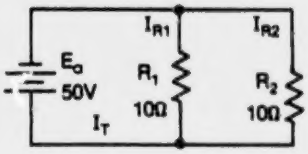
11. Calculate R_T. ________


R_1 20Ω
R_2 20Ω

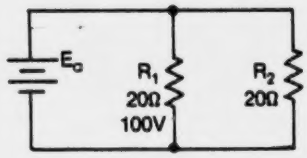
CURRENT AND VOLTAGE

Calculate the following using the illustration to the right.

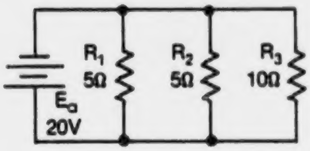
1. E_{R1} ________
2. I_{R2} ________
3. E_{R2} ________
4. I_{R2} ________
5. I_T ________


I_{R1}
I_{R2}
E_a
50V
R_1
10Ω
R_2
10Ω
I_T

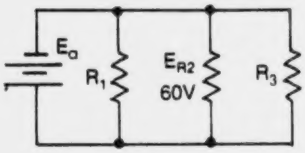
6. I_{R1} ________
7. E_{R2} ________
8. I_{R2} ________
9. I_T ________
10. E_a ________


E_a
R_1
20Ω
100V
R_2
20Ω

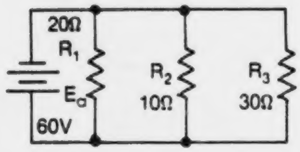
11. I_{R1} ________
12. I_{R2} ________
13. I_{R3} ________
14. I_T ________
15. E_{R1} ________
16. E_{R2} ________
17. E_{R3} ________


R_1
5Ω
R_2
5Ω
R_3
10Ω
E_a
20V

18. E_{R1} ________
19. E_{R3} ________
20. E_a ________


E_a
R_1
E_{R2}
60V
R_3

21. I_1 ________
22. I_2 ________


20Ω
R_1
E_a
60V
R_2
10Ω
R_3
30Ω

23. I_3 ________

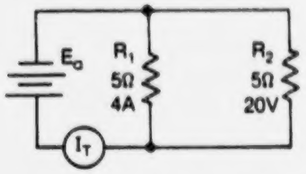
24. I_T ________

25. I_2 ________

26. I_T ________

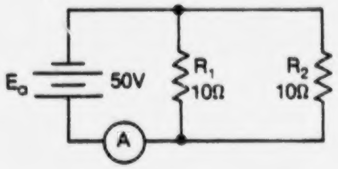
27. E_{R1} ________

28. E_a ________



E_a
R_1
5Ω
4A
R_2
5Ω
20V
I_T

29. If current is measured where the ammeter is located, what would be indicated? ________



E_a
50V
R_1
10Ω
R_2
10Ω
A

Calculate the following.

30. I_1 ________

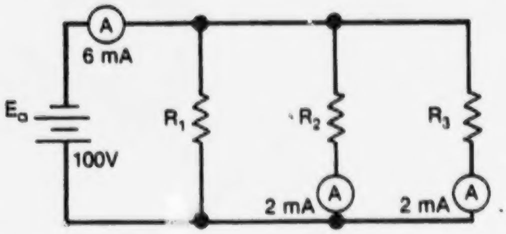
31. E_{R1} ________

32. E_a ________

33. I_T ________

34. E_{R2} ________

35. E_{R3} ________

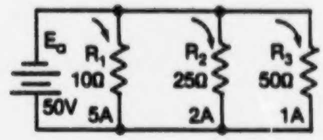


A
6 mA
E_a
100V
R_1
R_2
R_3
2 mA
A
2 mA
A

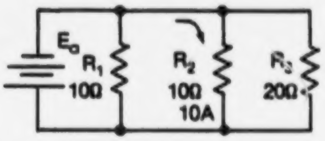
POWER

Calculate the following.

1. P_T = ________ watts

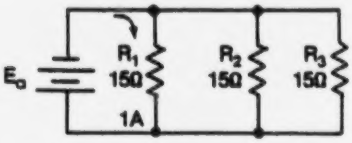

E
E_o
R_1
10Ω
R_2
25Ω
R_3
50Ω
50V
5A
2A
1A

2. P_T = ________ watts


E_o
R_1
10Ω
R_2
10Ω
10A
R_3
20Ω

NOTE: I_{R2} = 10A

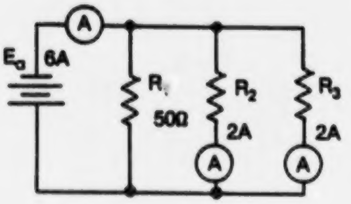
3. P_T = ________ watts


E_o
R_1
15Ω
1A
R_2
15Ω
R_3
15Ω

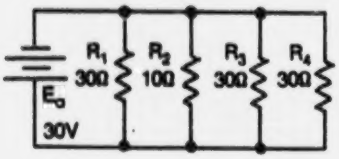
NOTE: I_{R1} = 1A

VARIOUS VALUES

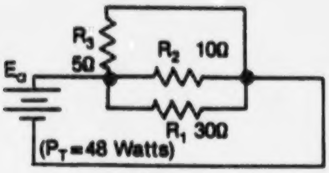
Calculate the following using illustrations on the left.


A
E_a
6A
R_1
50Ω
R_2
2A
A
R_3
2A
A

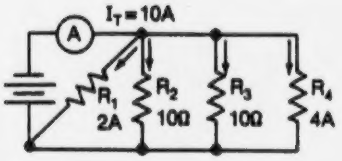
1. E_{R1} ________
2. E_a ________
3. R_T ________
4. R_2 ________
5. R_3 ________
6. P_T ________


R_1
30Ω
R_2
10Ω
R_3
30Ω
R_4
30Ω
E_a
30V

7. R_T ________
8. I_1 ________
9. I_2 ________
10. I_3 ________
11. I_4 ________
12. I_T ________


R_3
5Ω
R_2 10Ω
E_a
R_1 30Ω
(P_T=48 Watts)

13. R_T ________
14. I_T ________
15. E_a ________
16. I_{R1} ________


I_T=10A
A
R_1
2A
R_2
10Ω
R_3
10Ω
R_4
4A

17. E_a ________
18. R_4 ________
19. I_{R2} ________
20. I_{R3} ________
21. R_T ________
22. P_T ________

ANSWERS TO ASSIGNMENT SHEET 3.1

1. 20Ω
2. 30Ω
3. 12Ω
4. 12Ω
5. 10Ω
6. 10Ω, 30Ω
7. 20Ω
8. 20Ω
9. 12Ω
10. 20Ω
11. 10Ω

ANSWERS TO AS 3.2

1. 50V
2. 5V
3. 50V
4. 5A
5. 10A
6. 5A
7. 100V
8. 5A
9. 10A
10. 100V
11. 4A
12. 4A
13. 2A
14. 10A
15. 20V
16. 20V
17. 20V
18. 60V
19. 60V
20. 60V
21. 3A
22. 6A
23. 2A
24. 11A
25. 4A
26. 8A
27. 20V
28. 20V
29. 10A
30. 2ma
31. 100V
32. 100V
33. 6mA
34. 100V
35. 100V

ANSWERS TO AS 3.3

1. 400 watts
2. 2500 watts
3. 45 watts

ANSWERS TO AS 3.4

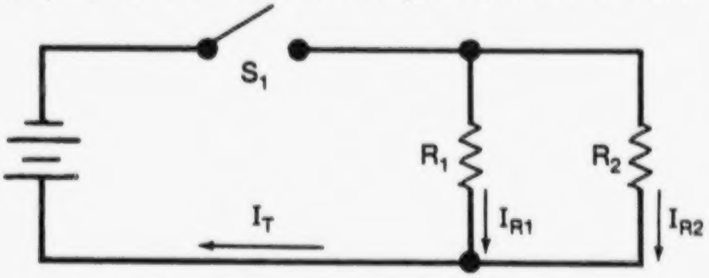
1. 100V
2. 100V
3. 16.7Ω
4. 50Ω
5. 50Ω
6. 600W
7. 5Ω
8. 1A
9. 3A
10. 1A
11. 1A
12. 6A
13. 3Ω
14. 4A
15. 12V
16. 0.4A or 400mA
17. 20V
18. 5Ω
19. 2A
20. 2A
21. 2Ω
22. 200W

MEASURE VOLTAGE, CURRENT AND RESISTANCE IN A PARALLEL CIRCUIT

Equipment:

Power source
Two small resistors of equal value or two small lamps
VOM or voltmeter
VOM or ammeter
Switch
Wire to complete circuit

Procedure:	Evaluation 3	 2	 1	 N
1. Construct a parallel resistive circuit according to the schematic below.	__	__	__	__



	3	2	1	N
2. Close switch S_1. Measure and record applied voltage (E_a). __________	__	__	__	__
3. Measure and record voltage across R_1 and across R_2. __________, __________ Compare recorded voltages. Are they all equal? (yes/no) Explain why.	__	__	__	__
4. Open switch S_1. Connect ammeter in series with R_1.	__	__	__	__
5. Close switch S_1 and read and record current (I_{R1}). __________	__	__	__	__
6. Open switch S_1. Disconnect ammeter from R_1 branch and connect it in series with R_2.	__	__	__	__
7. Close switch S_1. Read and record current (I_{R2}). __________	__	__	__	__
8. Open switch S_1. Disconnect ammeter from R_1 branch and connect it in series with the voltage source (E_a) and switch S_1.	__	__	__	__
9. Close switch S_1 and read and record main current (I_T). __________	__	__	__	__
10. Open switch S_1. __________, __________ Are recorded currents I_{R1} and I_{R2} equal? (yes/no) Explain why or why not.	__	__	__	__

11. Add I_{R1} and I_{R2}. ________ Does the sum equal I_T? (yes/no) Explain why or why not. — — — —

12. Close switch; if lamps were used for R_1 and R_2, note that both lamps are glowing. Disconnect R_2 from circuit. — — — —

13. Record ammeter indication and if R_1 and R_2 are lamps, note any changes in R_1 operation when R_2 (lamp) was removed. ________ — — — —

14. Replace R_2 and remove R_1 from circuit. Record ammeter indication and note any changes in R_2 operation, if applicable. ________ — — — —

15. Reconnect R_1. Using the voltmeter, read and record applied voltage (E_a), E_{R1} and E_{R2}. ________ , ________ , ________ — — — —

16. Using measured E_a and I_T, compute total resistance of the circuit (R_T). — — — —

____

17. Using measured voltage and current values, compute R_1 and R_2 and from these figures compute R_T. — — — —

If R_1 and R_2 are lamps, explain changes in lamp operation when one lamp was removed from the circuit.

18. Return equipment and materials to proper storage area. — — — —

Average of above evaluation* — — — —

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

MEASURE VOLTAGE, CURRENT AND RESISTANCE USING A POWER SUPPLY

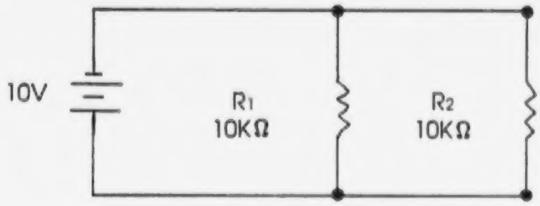
Equipment:

Power supply
Two 10KΩ, 1/8 watt (minimum) resistors
One 3.3KΩ, 1/8 watt (minimum) resistor
Multimeter
Circuit accessories

Evaluation
3 2 1 N

Procedure:

NOTE: Do not construct the circuit until instructed to do so.



1. Analyze the circuit above and predict the following values. _ _ _ _

a. V_{R1} =

b. V_{R2} =

c. I_{R1} =

d. I_{R2} =

e. R_T =

f. I_T =

2. Build the circuit and measure the following values. — — — —

a. V_{R1} =

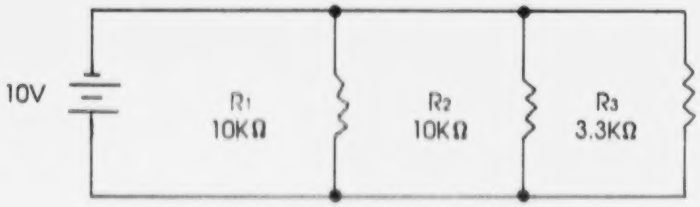
b. V_{R2} =

c. I_{R1} =

d. I_{R2} =

e. R_T =

f. I_T =



3. Analyze the circuit above and predict the following values. — — — —

a. V_{R1} =

b. V_{R2} =

c. V_{R3} =

d. I_{R1} =

e. I_{R2} =

f. I_{R3} =

g. R_T =

h. I_T =

4. Build the circuit and measure the following values. — — — —

a. V_{R1} =

b. V_{R2} =

c. V_{R3} =

d. I_{R1} =

e. I_{R2} =

f. I_{R3} =

g. R_T =

h. I_T =

5. Return all equipment to proper storage area. — — — —

Average of above evaluations* — — — —

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

LESSON 4: SERIES-PARALLEL CIRCUITS

I. Characteristics of series-parallel circuits

A. A series-parallel circuit is one in which some components are connected in series to have the same current, while others are connected in parallel and have the same voltage. (HO 4.1)

B. The characteristics or "rules" for current, voltage, resistance and power in series and parallel circuits are as follows.

	Rules for Parallel Circuits	*Rules for Series Circuits*
Current	Total current is the sum of the currents in the branches and the current in a branch varies inversely with the resistance of the branch. $I_T = I_1 + I_2 + I_3 \ldots$	Current is the same through all components in a series circuit. $I_T = I_1 = I_2 = I_3 = \ldots$
Voltage	Total voltage (applied voltage) is the same across all branches. $E_a = E_1 = E_2 = E_3 \ldots$	Sum of the voltage drops in a series circuit equals the applied voltage. The voltage drop varies directly with the resistance. $E_a = E_1 + E_2 + E_3 \ldots$
Resistance	Total resistance of a parallel circuit is always less than the resistance of any branch. The reciprocal of the total resistance equals the sum of the reciprocals of the parallel resistances.	Total resistance in a series circuit equals the sum of the individual resistances.
Power	The total power consumed in a parallel circuit equals the sum of the power consumed in each branch.	The total power consumed in a series circuit equals the sum of the power consumed in each component.

C. To determine values of E, I and R in series-parallel circuits, simplify the circuit to an equivalent series circuit. (HO 4.2-4.3)

1. Identify which are series components and which are parallel components (or groups of components).
2. Reduce each parallel group of components to an equivalent resistance (R_{EQ}).
3. Redraw the circuit using single equivalent resistors to represent each parallel group as determined in step 2.

NOTE: This new circuit is now a series circuit.

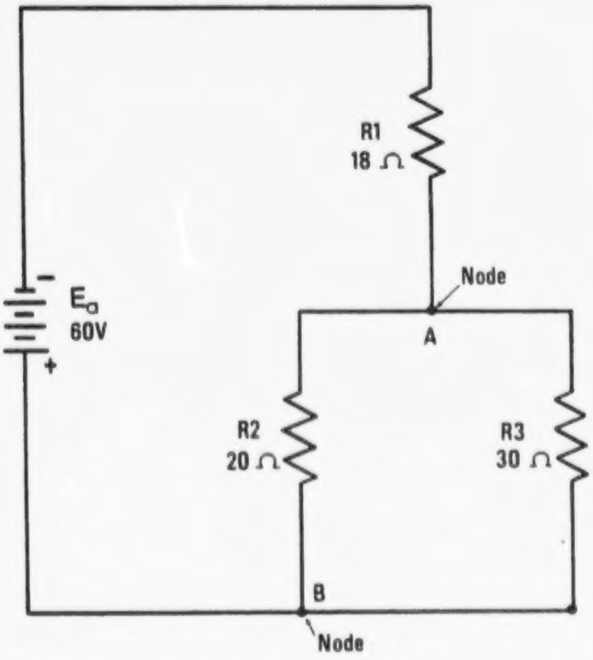
4. Combine all resistances in the new circuit to find total resistance (R).

5. Determine total current by dividing the applied voltage by the total resistance.

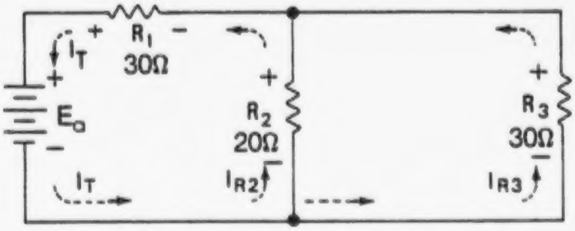
SERIES-PARALLEL AND EQUIVALENT CIRCUITS

Series-Parallel Circuit

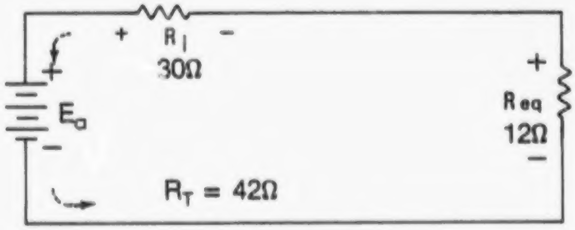
R_1 is in Series with the Parallel Branches R_2–R_3


R1
18 Ω
Node
A
E_a
60V
−
+
R2
20 Ω
R3
30 Ω
B
Node

Equivalent Circuit

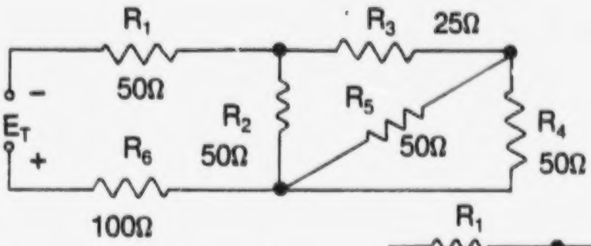

I_T
+
R_1
30Ω
−
E_a
+
−
R_2
20Ω
I_{R2}
R_3
30Ω
I_{R3}
I_T

Circuit

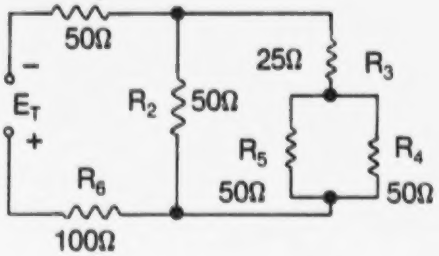

+
R_1
30Ω
−
E_a
R_{eq}
12Ω
R_T = 42Ω

Equivalent Circuit

CIRCUIT REDUCTION

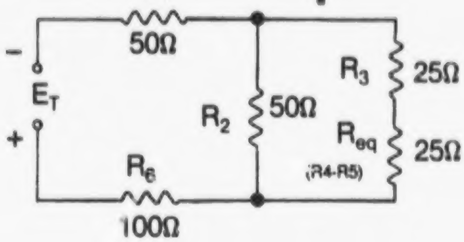

R₁
50Ω
R₃ 25Ω
−
E_T
+
R₂
50Ω
R₅
50Ω
R₄
50Ω
R₆
100Ω

Step A: Trace Current Flow
and Re-Draw Circuit

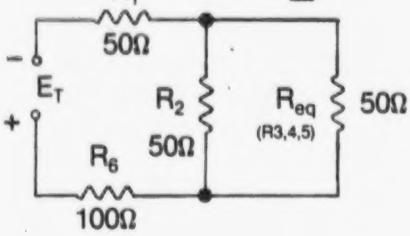

R₁
50Ω
−
E_T
+
R₂
50Ω
25Ω
R₃
R₅
50Ω
R₄
50Ω
R₆
100Ω

Step B: Reduce Circuit

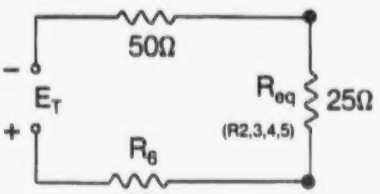
1


R₁
50Ω
−
E_T
+
R₂
50Ω
R₃
25Ω
R_eq
(R4-R5)
25Ω
R₆
100Ω

2

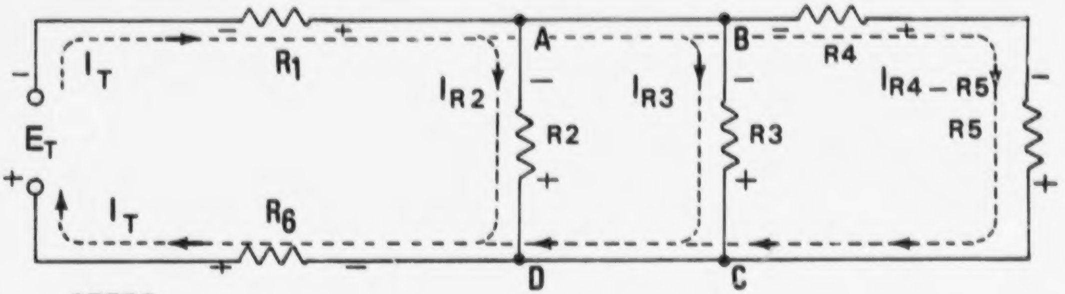

R₁
50Ω
−
E_T
+
R₂
50Ω
R_eq
(R3,4,5)
50Ω
R₆
100Ω

3


R₁
50Ω
−
E_T
+
R_eq
(R2,3,4,5)
25Ω
R₆
100Ω

$R_T = R_1 + R_{eq} + R_6 = 175\Omega$

SIMPLIFYING SERIES-PARALLEL

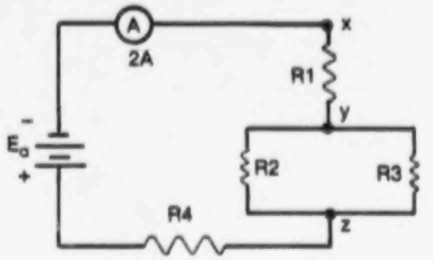


STEPS:

1. Trace Current Flow and Identify Voltage Drop Polarity (See Above)
2. Identify Nodes
   a. Current Division — A & B
   b. Current Return — C & D
3. Identify Resistors in Series With E_T: R1 & R6
4. Identify Resistors in Parallel: R2, R3, & (R4 + R5)
5. Identify Series-Parallel Resistors:
   a. R2, R3, & (R4 + R5) Become R_{eq} When the Reciprocal Resistance Formula is Applied
   b. R1 & R6 are in Series with R_{eq}
6. Determine Total Resistance: RT = R1 + R_{eq} + R6

CURRENT FLOW

Complete statements or answer questions below after studying the schematic.



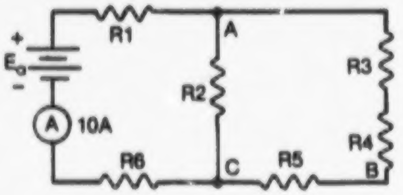
1. Current will divide at Point ________ and come back together at Point ____________ .

2. List resistors that are in series (__________) and those that are in parallel. (_________)

____ 3. Resistors 2 and 3 will _________ of current.

- a. Carry a combined two amps
- b. Each carry two amps
- c. Carry a combined one amp
- d. Each carry less than two amps
- e. None of the above

Study the schematic and answer the questions below.



4. a. At what point does current divide?

   b. At what point does it come back together?

   c. Does current divide more than once?

5. List the three resistors in the circuit that form a series string.

   a.

   b.

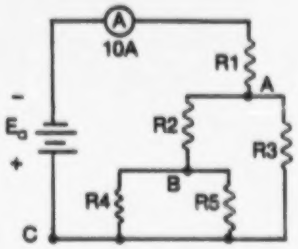
   c.

6. List the resistors in series with the source.

___ 7. Which of the statements about the circuit above are correct?

a. R2 is in parallel with R3, R4 and R5.
b. Less than 10 amps will flow through R2.
c. 10 amps will flow through R6.
d. Fewer than 10 amps will flow through R3, R4 and R5.
e. All of the above

Study the schematic and answer the questions below.



8. At what point does current first divide? _________ Next divide? _____ Come back together? _____

___ 9. Which pairs of resistors are in parallel with each other?

a. R1 and R3
b. R2 and R4
c. R2 and R5
d. R4 and R5

10. How many resistors are directly in series with the rest of the circuit? ___________ Is the R_{EQ} of R4 and R5 in series with R2? _________

11. Place a check mark before the incorrect statement(s).

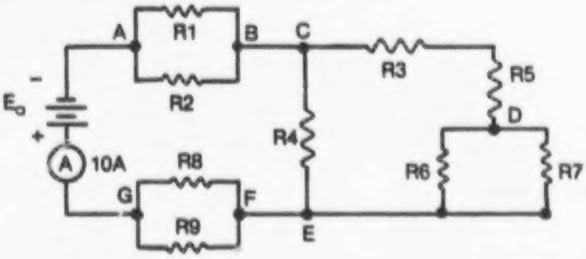
___ a. $I_{R2} + I_{R3} = 10$ amps

___ b. An ammeter at Point C will measure 10 amps.

___ c. Current through R5 will be more than through R1.

___ d. $I_{R4} + I_{R5} = I_{R2}$

Study the schematic and answer the questions below.



12. Current first divides at which point? ______________________

13. Current next divides at which point? ______________________

14. Does current also divide at Point D? _________ Point F? _________

15. How many resistors are in series with the source? _________

16. Will there be a full 10 amps of current through R7? _________

17. Will there be a full 10 amps of current through R4? _________

18. Will there be a full 10 amps of current at Point G? _________

19. Does the total current go through R2? _________

20. Does a full 10 amps enter R9? _________

21. Will the current be common through R3 and R5? _________

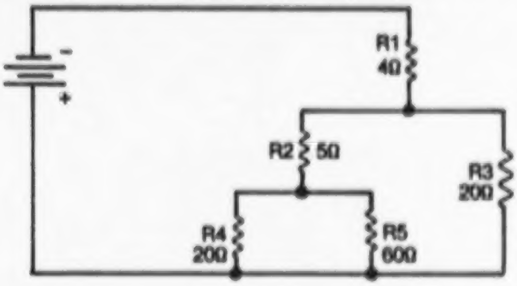
22. Does the full 10 amps of current enter Point D? _________

23. Name the two resistors in series. _________

AS 4.2

TOTAL RESISTANCE

This assignment combines circuit reductions and problems in solving for total circuit resistance in more complex circuits. Use the steps listed in the information sheets and refer to it, if necessary. Study the circuit below. Trace current flow and determine which resistors are in parallel.



1. Find R_{EQ} for R4 and R5. ______________________

2. Redraw the circuit, showing R4 and R5 combined into one equivalent resistor. Show values.

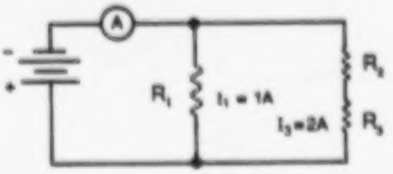
3. Note that R2 and R_{EQ} are now in series and are additive. Combine R2 and R_{EQ} into one equivalent resistor, R_{EQ}. Redraw the circuit and show values.

4. Notice now that the R_{EQ} is in parallel with R3. Find the next R_{EQ} and redraw the circuit with appropriate values shown.

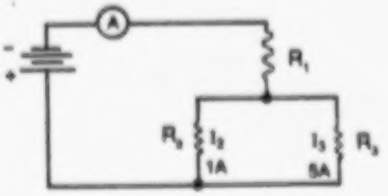
5. Redraw the final circuit showing one equivalent resistor, R_T.

TOTAL CURRENT AND VOLTAGE

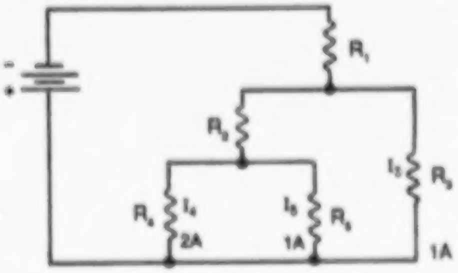
1. In the circuit below, I_T = ______________ .


A
-
+
R1
I1 = 1A
I3=2A
R2
R3

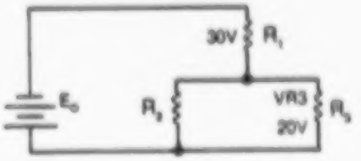
2. In the circuit below, I_T = ______________ .


A
-
+
R1
R2
I2
1A
I3
5A
R3

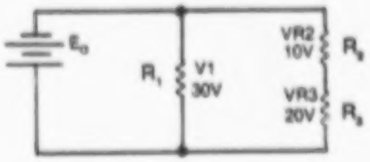
3. In the circuit below, I_T = ______________ .


-
+
R1
R2
I3
R3
R4
I4
2A
I5
1A
R5
1A

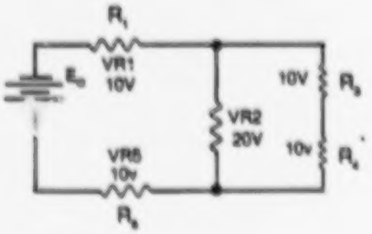
4. In the circuit below, E_a = ________________ .


30V
R1
Ea
R2
VR3
20V
R3

5. In this circuit, E_a = ______ .

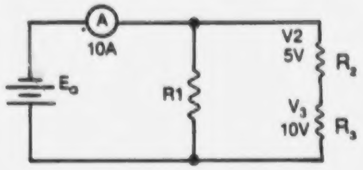

Ea
R1
V1
30V
VR2
10V
R2
VR3
20V
R3

6. In this circuit, E_a = ________ .

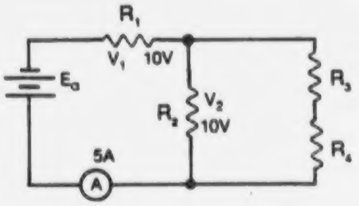

R_1
E_a
VR1
10V
10V
R_3
VR2
20V
10v
R_4
VR5
10v
R_5

TOTAL POWER

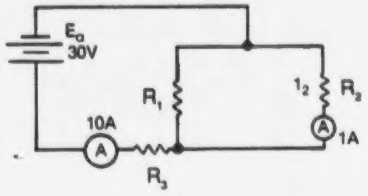
1. In the circuit below, P_T = ____________ .


A
10A
E_a
R1
V2
5V
R2
V3
10V
R3

2. In the circuit below, P_T = ____________ .


R1
V1 10V
E_a
R2
V2
10V
R3
R4
5A
A

3. In the circuit below, P_T = ____________ .


E_a
30V
R1
I2
R2
A
1A
10A
A
R3

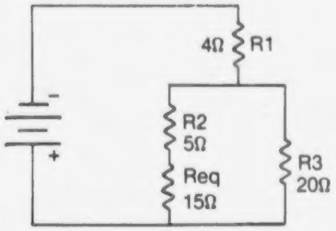
ANSWERS TO ASSIGNMENT SHEET 4.1

1. Y, Z
2. R_1 and R_4, R_2 and R_3
3. a and d
4. C, A, no
5. R_3, R_4, R_5
6. R_1, R_6
7. e
8. A, B, C
9. d
10. One (R_1), yes
11. c
12. Point A
13. Point C
14. Yes, yes
15. None
16. No
17. No
18. Yes
19. No
20. No
21. Yes
22. No
23. R_3 and R_5

ANSWERS TO AS 4.2

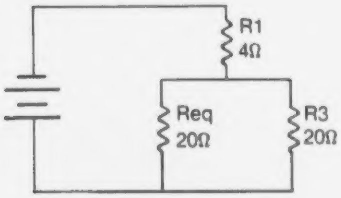
1. 15Ω

2.



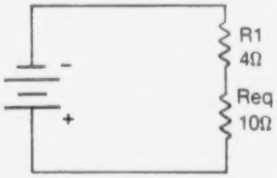
–
+
4Ω
R1
R2
5Ω
Req
15Ω
R3
20Ω

3.



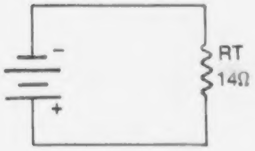
R1
4Ω
Req
20Ω
R3
20Ω

4.



–
+
R1
4Ω
Req
10Ω

5.



ANSWERS TO AS 4.3

1. 3A
2. 6A
3. 4A
4. 50V
5. 30V
6. 40V

ANSWERS TO AS 4.4

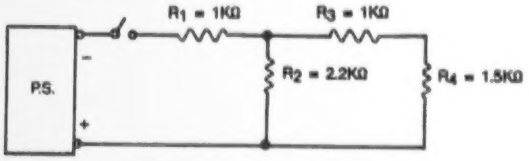
1. 150 watts
2. 100 watts
3. 300 watts

ANALYZE A SERIES-PARALLEL CIRCUIT

Equipment:

DC power supply
Multimeter
Resistors: two 1000Ω, one 1500Ω and one 2200Ω, 1/8W (minimum)
Switch (SPST)

Procedure:	Evaluation 3	 2	 1	 N
1. Connect the resistors as shown in the schematic.	—	—	—	—



2. Adjust the power supply per instructor and close the switch. Measure and record the voltage drop across each resistor (V_1, V_2 . . .).	—	—	—	—
3. Measure and record the current through each resistor (I_1, I_2 . . .).	—	—	—	—
4. Compute the power used by each resistor using the values measured in steps 2 and 3 ($P_1 = E_1 I_1$,etc.).	—	—	—	—
5. Measure and record E_A and I_T.	—	—	—	—
6. Compute R_T using the measurements of step 5.	—	—	—	—
7. Compute R_1, R_2, R_3 and R_4 using the voltage drops and currents measured in steps 2 and 3.	—	—	—	—
8. Compute R_T using the resistance values computed in step 7.	—	—	—	—
9. Return equipment and materials to their proper storage area.	—	—	—	—
Average of above evaluation*	—	—	—	—

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

INSTRUCTOR'S NOTE: The following questions can be discussed with the class.

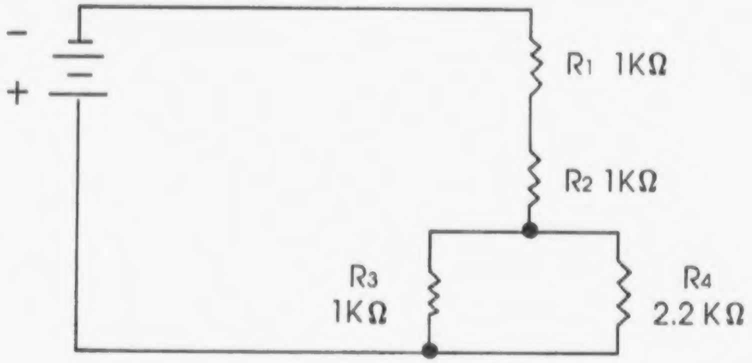
1. Did the value of R_T computed in step 6 differ from step 7? Explain.
2. Why does the resistance computed using the voltage drop and current differ from the color-coded value?
3. How much difference can be permitted between the computed and the color-coded values of a resistor? Why?
4. Does the total power (IE) equal the total power computed in step 4? Explain any differences.

JS 4.2

ANALYZE A SERIES-PARALLEL CIRCUIT

Equipment:

Power supply
Three 1KΩ, 1/8 watt (minimum) resistors
One 2.2KΩ, 1/8 watt (minimum) resistor
Multimeter
Circuit accessories



Procedure:

Evaluation
3 2 1 N

NOTE: Do not construct the circuit until instructed to do so.

1. Analyze the circuit above for the following values. — — — —

   a. V_{R1} =
   b. V_{R2} =
   c. V_{R3} =
   d. V_{R4} =
   e. I_{R1} =
   f. I_{R2} =
   g. I_{R3} =
   h. I_{R4} =
   i. R_T =
   j. I_T =

2. Does $V_{R1} = V_{R2}$? _________ Should it? _________ Why? — — — —

3. Does $I_{R1} = I_{R2}$? _________ Should it? _________ Why? — — — —

4. Does $I_{R2} = I_{R3} + I_{R4}$? _________ Should it? _________ Why? — — — —

5. Construct the circuit and measure the following values. — — — —

a. V_{R1} =

b. V_{R2} =

c. V_{R3} =

d. V_{R4} =

e. I_{R1} =

f. I_{R2} =

g. I_{R3} =

h. I_{R4} =

i. R_T =

j. I_T =

6. Return all equipment to proper storage area. — — — —

Average of above evaluations* — — — —

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

LESSON 5: VOLTAGE- AND CURRENT-DIVIDER CIRCUITS

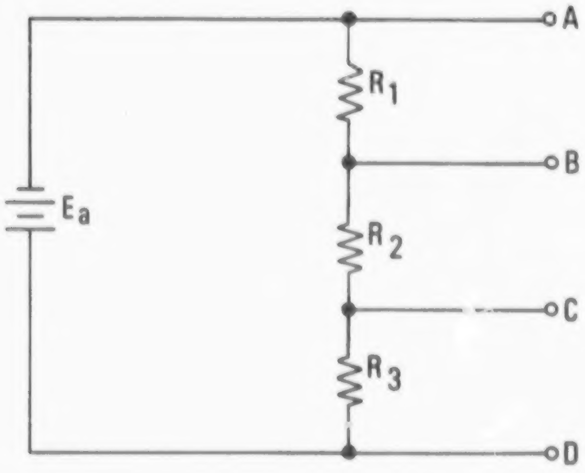
I. Voltage-divider characteristics

A. A voltage divider is a circuit that can be used to provide, from a single DC source, different voltage values to different loads--each of which can draw a different value of current. (TM 5.1)

1. A voltage-divider circuit consists of two or more resistors connected in series across a single power source.
2. The fraction of voltage required by a load or loads can be tapped off as the voltage is dropped through successive steps of the series resistors.
3. The values of the series resistors are determined by the voltage drops required.
4. If a chassis ground is used, both negative and positive voltages can be obtained from a single source.

B. Two types of voltage dividers: unloaded and loaded

1. Unloaded--the series string of resistors without a current drawing load attached



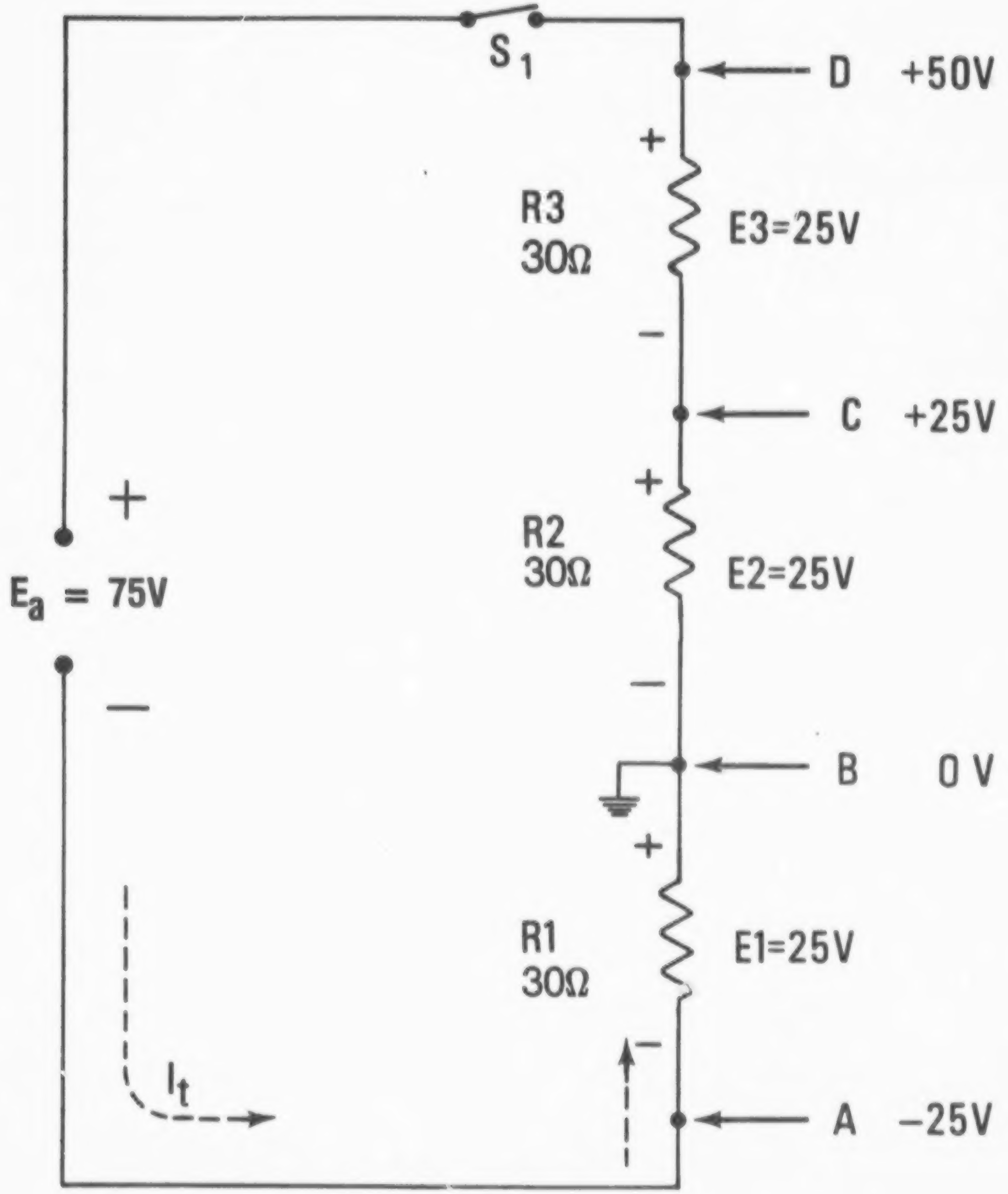
2. Loaded--load is attached (in parallel) to the divider network (TM 5.2, shown for a comparison only)

C. Voltage-divider formula

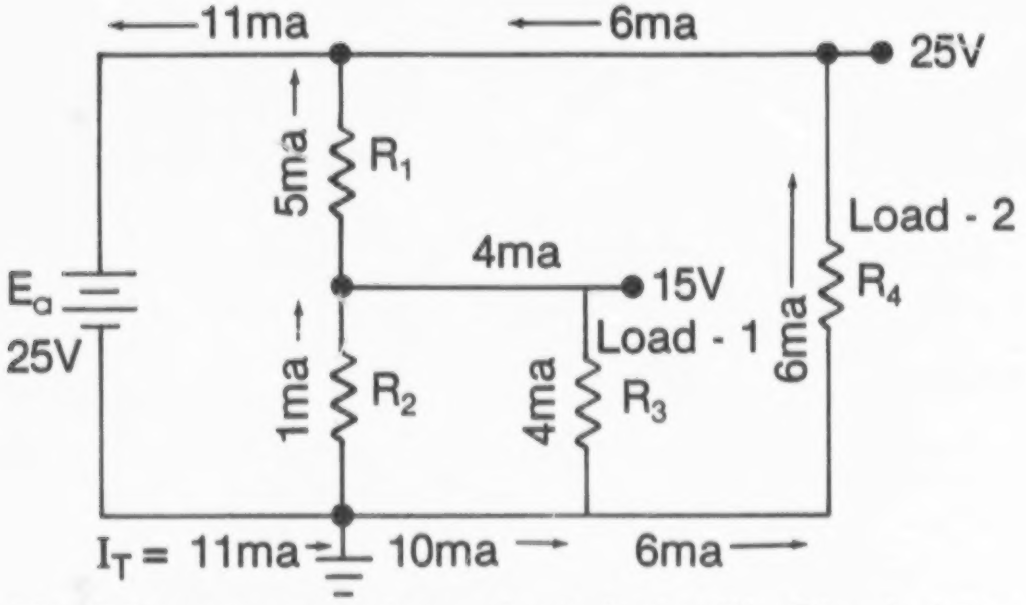
$$V_{RX} = \frac{V_T \times R_x}{R_T}$$

where R_x = one of the individual resistances in a series circuit

VOLTAGE DIVIDER


S 1
D +50V
+
R3
30Ω
E3=25V
–
C +25V
+
R2
30Ω
E2=25V
–
B 0 V
+
R1
30Ω
E1=25V
–
A –25V
+
E_a = 75V
–
I_t

LOADED VOLTAGE DIVIDER


11ma
6ma
25V
5ma
R_1
Load - 2
4ma
E_a
25V
15V
R_4
Load - 1
6ma
1ma
R_2
4ma
R_3
I_T = 11ma
10ma
6ma

Resistances may be calculated with Ohm's Law

$$R_1 = \frac{E_{R1}}{I_{R1}} = \frac{10V}{.005A} = 2000\Omega\ (2K\Omega)$$

$$R_2 = \frac{E_{R2}}{I_{R2}} = \frac{15V}{.001A} = 15000\Omega\ (15K\Omega)$$

$$R_3 = \frac{E_{R3}}{I_{R3}} = \frac{15V}{.004} = 3750\Omega\ (3.75K\Omega)$$

$$R_4 = \frac{E_{R4}}{I_{R4}} = \frac{25V}{.006A} = 4164\Omega\ (4.16K\Omega)$$

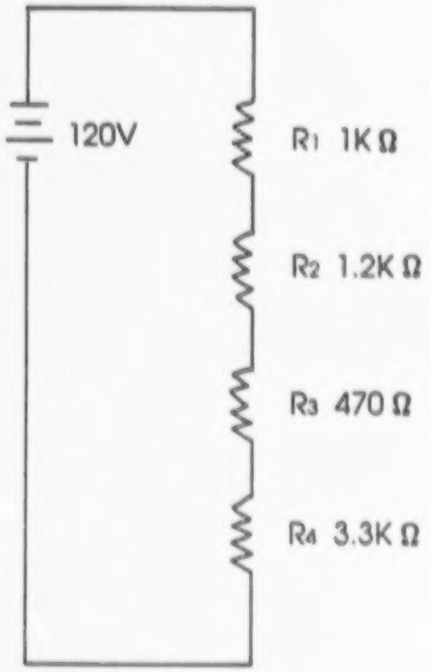
VOLTAGE DIVIDER

1. In the circuit to the right, V_{R1} = ______________ .

2. V_{R2} = ______________ .

3. V_{R3} = ______________ .

4. V_{R4} = ______________ .


120V
R_1 1K Ω
R_2 1.2K Ω
R_3 470 Ω
R_4 3.3K Ω

ANSWERS TO ASSIGNMENT SHEET 5.1

1. 20.1V
2. 24.1V
3. 9.4V
4. 66.3V

JS 5.1

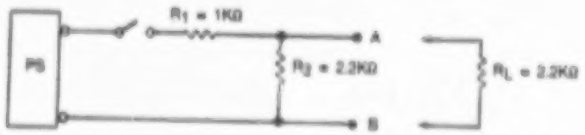
CONSTRUCT AND ANALYZE A VOLTAGE DIVIDER

Equipment:

DC power supply
Multimeter
One 1000Ω and two 2200Ω resistors, 1/8W (minimum)

Procedure: Evaluation
3 2 1 N

1. Connect the resistors in series with the power supply as shown in the following schematic. — — — —



2. Adjust the power supply per instructor. Close the switch; measure and record V_{R2} and V_{R1}. — — — —

3. Connect the load across points A and B. Read and record the voltage across R_1 and R_2 with the load connected. — — — —

4. Explain why V_{R1} changed when the load was connected; explain the direction of the change. — — — —

5. Explain differences observed in V_2 with and without the load. — — — —

6. Return equipment and materials to their proper storage area. — — — —

Average of above evaluation* — — — —

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

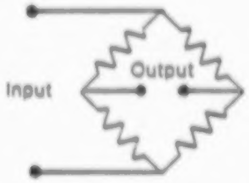
MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

LESSON 6: BRIDGE CIRCUITS

I. Terms and definitions

A. Bridge--a four-component device that uses two nodes as inputs and two as outputs or references



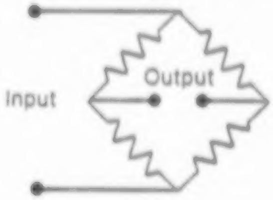
B. Balanced bridge--a bridge circuit that meets one of the following conditions: (1) outputs are at the same relative voltage or (2) the ratio of top resistors is equal to the respective lower resistors

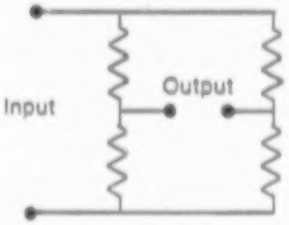
C. Unbalanced bridge--a bridge circuit that does not meet the conditions of a balanced bridge

D. Wheatstone bridge--a special application of a bridge circuit used to measure resistance

II. Types of bridges

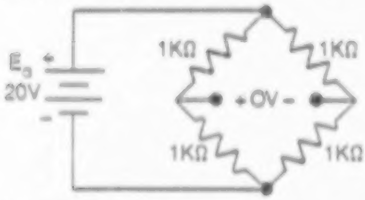
A. A simple bridge circuit is a series-parallel circuit which has two input terminals and two output terminals.

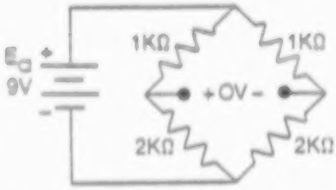




NOTE: The "bridge" is the component or device which is connected across the output terminal, frequently a meter.

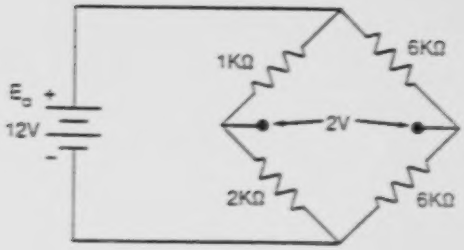
B. A balanced bridge circuit is one with components adjusted so that output voltage is zero.



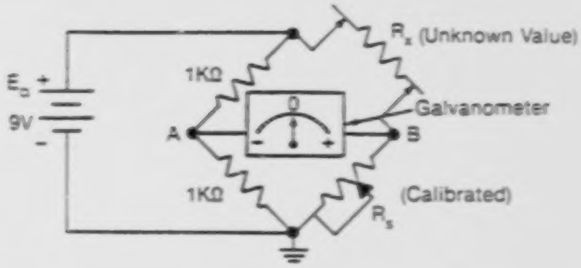


NOTE: In the figure on the left, the resistors have the same value and the voltage across the output terminals is zero. The circuit on the right has unequal resistors and the voltage across the output terminals is also zero because the voltage division within each branch is in equal proportions.

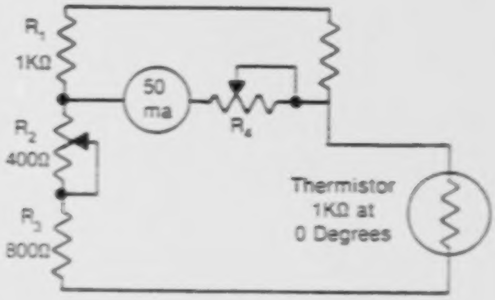
C. An unbalanced bridge circuit has a potential difference across the output terminals of the circuit.


1KΩ
6KΩ
E_s +
12V
-
2V
2KΩ
6KΩ

D. The wheatstone bridge is a practical application of a bridge circuit and is used for measuring resistance.


R_x (Unknown Value)
1KΩ
E_s +
9V
-
0
Galvanometer
A
B
1KΩ
(Calibrated)
R_s

E. Bridge circuits have many applications in control and instrumentation circuits and devices.


R_1
1KΩ
50
ma
R_4
R_2
400Ω
R_3
800Ω
Thermistor
1KΩ at
0 Degrees

MEASURE VOLTAGES

Equipment:

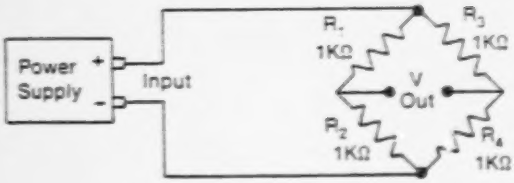
Balanced bridge circuit:	Unbalanced bridge circuit:
Power supply	Power supply
Voltmeter (or multimeter)	Voltmeter (or multimeter)
Four 1000Ω resistors	Decade box or 10KΩ potentiometer

Evaluation
3 2 1 N

Procedure:

Balanced circuit

1. Connect the circuit according to the following. ___ ___ ___ ___


Power Supply
+
-
Input
R₁ 1KΩ
R₃ 1KΩ
V Out
R₂ 1KΩ
R₄ 1KΩ

2. Apply 10 volts DC to circuit input. Use a voltmeter to read and record the voltage drop across each resistor and the output terminals. ___ ___ ___ ___

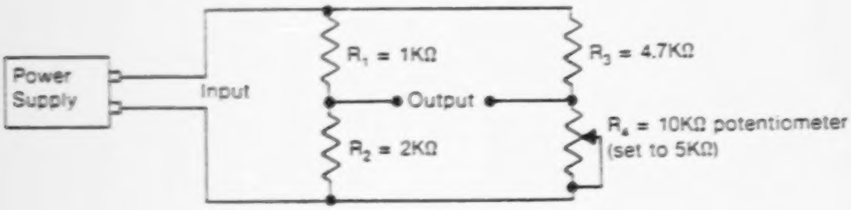
E_{R1} = __________ E_{R3} = ________ E_{out} = ________

E_{R2} = __________ E_{R4} = ________

NOTE: Notice how voltage drops are equal across the resistors.

Unbalanced circuit

3. Connect the circuit according to the following. ___ ___ ___ ___


Power Supply
Input
R_1 = 1KΩ
R_3 = 4.7KΩ
Output
R_2 = 2KΩ
R_4 = 10KΩ potentiometer (set to 5KΩ)

4. Apply 12 volts DC to the circuit. Use a voltmeter to measure voltage drops across each of the resistors and the voltage between the output terminals. ___ ___ ___ ___

E_{R1} = ______ E_{R3} = ______ E_{out} = ______

E_{R2} = ______ E_{R4} = ______

5. Vary the potentiometer. Measure the output voltage. What happened when R_4 was varied? ___ ___ ___ ___

6. Return equipment and materials to their proper storage area. ___ ___ ___ ___

Average of above evaluation* ___ ___ ___ ___

*This average is the student's partial evaluation for competency B15: Calculate series and parallel; resistive, capacitive and inductive networks.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VI: CIRCUITS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. A resistor that is yellow, violet, red and gold is ____________.

a. 47kΩ
b. 27kΩ
c. 4.7kΩ
d. 2.7kΩ
e. None of the above

____ 2. A resistor is gray, red, orange and silver. The largest value this resistor should have is __________ .

a. 82kΩ
b. 83kΩ
c. Less than 90kΩ
d. More than 90kΩ
e. ±1%

____ 3. The power rating of a resistor is determined by the __________ .

a. Last color band
b. Physical size
c. Lead length
d. Color of the body of the resistor
e. All of the above

____ 4. A 47.2Ω ±1% resistor will have the colors of __________ .

a. Yellow, violet, red, orange, gold
b. Yellow, violet, red, red
c. Yellow, violet, red, gold, brown
d. Yellow, violet, orange, orange, brown
e. None of the above

____ 5. A 3.3Ω ±10% resistor is colored __________ .

a. Orange, orange, silver, gold
b. Red, red, silver, gold
c. Orange, orange, gold, silver
d. Red, red, gold, silver
e. None of the above

____ 6. A two-lead variable resistor is called a rheostat. A three-lead variable resistor is called a __________.

a. Triostat
b. Potentiometer
c. Triastor
d. Varistor
e. None of the above

____ 7. Which law states that the sum of voltages dropped is equal to applied voltage?

a. Kirchhoff's
b. Ohm's
c. Boole's
d. Coulomb's
e. None of the above

____ 8. The current in a series circuit __________ .

a. Follows only one path
b. Follows at least two paths
c. Follows less than three paths
d. Varies at any given point in the circuit
e. None of the above

____ 9. The applied voltage in figure 1 is __________ .

a. 12V
b. 13V
c. 15V
d. 18V
e. None of the above

____ 10. The applied voltage in figure 2 is __________ .

a. 22V
b. 25V
c. 28V
d. 32V
e. None of the above

____ 11. Total current in figure 2 is __________ .

a. 12.5mA
b. 10mA
c. 9.5mA
d. 5.0mA
e. None of the above

Figure 1

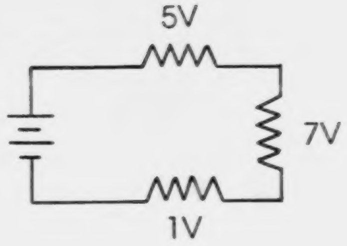
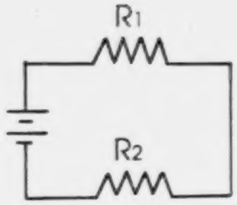
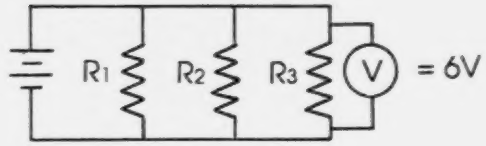


Figure 2



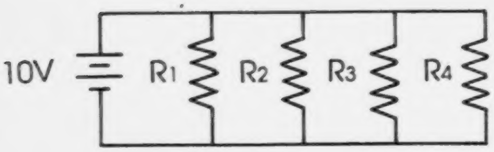
$R_1 = 4K\Omega$
$R_2 = 5K\Omega$
$I_{R1} = 5mA$

Figure 3



$R_1 = 250\Omega$
$R_2 = 500\Omega$
$R_3 = 500\Omega$

Figure 4


10V
R1
R2
R3
R4

All Resistors are 100Ω

____ 12. The total power dissipated in figure 2 is ________ .

a. 225mW
b. 470mW
c. 330mW
d. 150mW
e. None of the above

____ 13. Equivalent resistance in figure 2 is ________ .

a. 4kΩ
b. 5kΩ
c. 1kΩ
d. 9kΩ
e. None of the above

____ 14. The voltage across R_1 in figure 2 is ________ .

a. 36V
b. 25V
c. 20V
d. 2V
e. None of the above

____ 15. The voltage in a multiple branch parallel circuit is ________ .

a. Always the same
b. Dependent upon individual branches
c. Dependent upon the values of the resistors
d. Always less than the applied voltage
e. None of the above

____ 16. Current in one branch of a parallel circuit is ________ .

a. Always the same in each branch
b. Dependent upon the total circuit resistance
c. Dependent upon the resistance of that branch
d. Affected by the resistance in the other branches
e. All of the above

____ 17. Total voltage in figure 3 is ________ .

a. 6V
b. 12V
c. 18V
d. 24V
e. None of the above

____ 18. The voltage across R_2 in figure 3 is ________ .

a. 6V
b. 12V
c. 18V
d. 24V
e. None of the above

____ 19. The current of R_1 in figure 3 is ____ ____ .

a. 6mA
b. 2mA
c. 18mA
d. 24mA
e. None of the above

____ 20. The total resistance in figure 3 is __________ .

a. 250Ω
b. 500Ω
c. 1250Ω
d. 125Ω
e. None of the above

____ 21. Figure 4's equivalent resistance is __________ .

a. 25Ω
b. 36Ω
c. 42Ω
d. 45Ω
e. None of the above

____ 22. Power dissipated by the entire circuit in figure 4 is ________.

a. 1W
b. 4W
c. 5W
d. 10W
e. None of the above

____ 23. The current through R_4 in figure 4 is __________ .

a. 25mA
b. 50mA
c. 100mA
d. 200mA
e. Unable to be determined

____ 24. Current through R_1 in figure 5 is __________ .

a. 2.3mA
b. 6.7mA
c. 8mA
d. 20mA
e. None of the above

____ 25. The total power dissipated in figure 5 is __________ .

a. 400mW
b. 333mW
c. 66.7mW
d. 800mW
e. 160mW

____ 26. Voltage of R_1 in figure 8 is __________ .

a. 1V
b. 2V
c. 4V
d. 10V
e. None of the above

____ 27. Voltage of R_4 in figure 8 is __________ .

a. 1V
b. 2V
c. 4V
d. 10V
e. None of the above

____ 28. The current through R_2 in figure 5 is __________ .

a. 8.33mA
b. 5.56mA
c. 16.7mA
d. 6.67mA
e. None of the above

____ 29. The circuit in figure 6 is a(n) __________ .

a. Balanced bridge
b. Unbalanced bridge
c. Converter circuit
d. Bridge rectifier
e. None of the above

____ 30. Voltage across points A and B in figure 6 is __________ .

a. 0V
b. 2V
c. 3V
d. 4V
e. None of the above

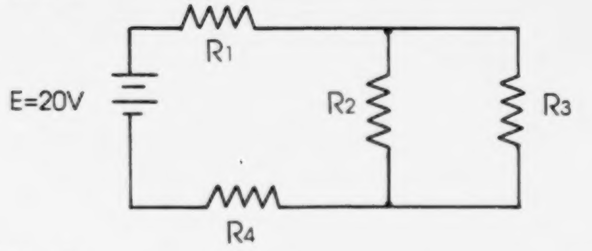
____ 31. To balance the circuit in figure 7, R_4 should be __________ .

a. 12kΩ
b. 10kΩ
c. 8kΩ
d. 6kΩ
e. None of the above

____ 32. Adding a resistor in parallel with one voltage-divider resistor causes the voltage of that voltage-divider resistor to __________ .

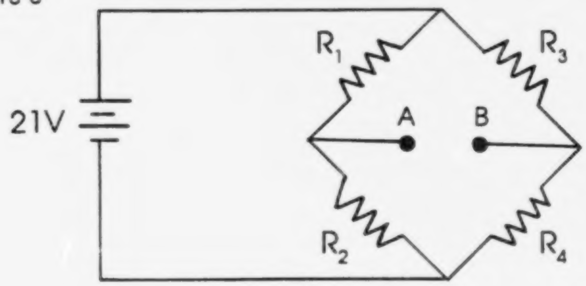
a. Always increase
b. Always decrease
c. Increase if the added resistance is the larger of the two
d. Decrease if the added resistance is the smaller of the two
e. Not change

Figure 5


E=20V
R1
R2
R3
R4

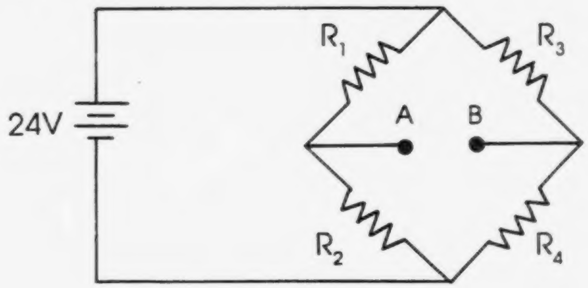
R1 = 1K Ω
R2 = 1.2K Ω
R3 = 6K Ω
R4 = 500 Ω

Figure 6


21V
R1
R3
A
B
R2
R4

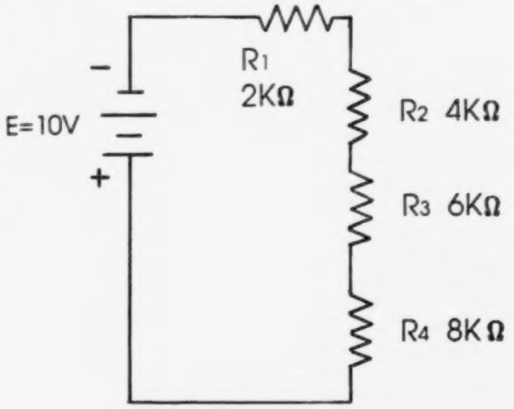
R1 = 1KΩ
R2 = 2KΩ
R3 = 3KΩ
R4 = 4KΩ

Figure 7


24V
R1
R3
A
B
R2
R4

R1 = 5KΩ
R2 = 15KΩ
R3 = 2KΩ
R4 = ______

Figure 8


–
E=10V
+
R1
2KΩ
R2 4KΩ
R3 6KΩ
R4 8KΩ

Match the following terms and definitions.

____ 33. Color band that indicates the number of zeros to add to preceding digits in order to determine the resistor's exact value

____ 34. Amount of variance from the actual stated value of a resistor allowed by the manufacturer

____ 35. Common return circuit with a voltage that is not necessarily the same as earth ground

____ 36. Method of placing specific values on components without placing numbers on the body of the component

____ 37. One of several current paths available to conduct current

____ 38. Circuit that has a complete and unbroken path for the flow of current

____ 39. Common return path with a voltage of zero compared to earth ground

____ 40. Device designed to be supplied with electrical energy

____ 41. Circuit that contains only one path for current

____ 42. Loss of electrical force (voltage) in a component; observed by measuring the voltage across that component

____ 43. Connection of three or more conductors where currents can either split or join

____ 44. Four-component device that uses two nodes as inputs and two as outputs or references

____ 45. Bridge circuit with (1) outputs at the same relative voltage or (2) an equal ratio of top resistors to respective lower resistors

____ 46. Special bridge circuit application used to measure resistance

a. Balanced bridge

b. Branch

c. Bridge

d. Chassis ground

e. Closed circuit

ab. Color code

ac. Ground

ad. Load

ae. Multiplier

bc. Node (junction)

bd. Open circuit

be. Series circuit

cd. Tolerance

ce. Voltage drop

de. Wheatstone bridge

ANSWERS TO UNIT TEST

1.	c	(B12)
2.	d	(B12)
3.	b	(B12)
4.	a	(B12)
5.	c	(B12)
6.	b	(B12)
7.	a	(B15)
8.	a	(B15)
9.	b	(B15)
10.	e	(B15)
11.	d	(B15)
12.	a	(B15)
13.	d	(B15)
14.	c	(B15)
15.	a	(B15)
16.	c	(B15)
17.	a	(B15)
18.	a	(B15)
19.	d	(B15)
20.	d	(B15)
21.	a	(B15)
22.	b	(B15)
23.	c	(B15)
24.	c	(B15)
25.	e	(B15)
26.	a	(B15)
27.	c	(B15)
28.	d	(B15)
29.	b	(B15)
30.	b	(B15)
31.	d	(B15)
32.	b	(B15)
33.	ae	
34.	cd	
35.	d	
36.	ab	
37.	b	
38.	e	
39.	ac	
40.	ad	
41.	be	
42.	ce	
43.	bc	
44.	c	
45.	a	
46.	de	

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VII: ELECTROMAGNETICS AND ELECTROSTATICS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to describe magnetic properties, electromagnetic and electrostatic devices, and the effects of such devices on circuits. This knowledge will be evidenced by achieving a specified score on the unit test and job sheets.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Identify terms and definitions.

1.2 Describe magnetism. (competency B4)

1.3 Describe the relationship between electricity and magnetism. (competency B3)

1.4 Use the correct formulas to solve for inductors in combination. (competency B10)

1.5 Identify the effect of inductors on circuit performance. (competency B14)

2.1 Identify terms and definitions.

2.2 Describe electrostatic effects (capacitance). (competency B9)

2.3 Identify types of capacitors. (competency B13)

2.4 Use the appropriate formulas to solve for capacitors in combination.

2.5 Calculate RC time constants. (competency B18)

2.6 Test capacitors. (competency B13, JS 2.1)

2.7 Calculate time constants. (competency B18, JS 2.2 and 2.3)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VII: ELECTROMAGNETICS AND ELECTROSTATICS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: MAGNETISM

    a. Information outline

    b. Transparency masters

        TM 1.1: Magnetic poles
        TM 1.2: Producing artificial magnets
        TM 1.3: Magnetic field around a current-carrying conductor
        TM 1.4: Concentration of lines of flux
        TM 1.5: Induced current
        TM 1.6: Electromagnetic induction
        TM 1.7: RL circuit and current rise
        TM 1.8: Power in RL circuits

    c. Handouts

        HO 1.1: Magnetic lines of force, flux and flux density
        HO 1.2: Left-hand rule for magnetic lines of flux and electromagnets
        HO 1.3: Simple AC generator and the left-hand generator rule
        HO 1.4: Concentration of lines of flux
        HO 1.5: Current rise and decay in an inductor

    d. Assignment sheets

        AS 1.1: Current flow direction and induction
        AS 1.2: Total inductance and time constants

    e. Answers to assignment sheets

2. Lesson 2: ELECTROSTATIC DEVICES (CAPACITORS)

    a. Information outline

    b. Transparency masters

        TM 2.1: Capacitor construction and electric field effect on dielectrics
        TM 2.2: Universal time constant chart for RC and RL circuits

    c. Handout

        HO 2.1: Plate area and distance

d. Assignment sheets

AS 2.1:	Total capacitance values
AS 2.2:	RC time constants

e. Answers to assignment sheets

f. Job sheets

JS 2.1:	Test capacitors with an ohmmeter
JS 2.2:	Construct a neon lamp flash circuit
JS 2.3:	Determine time constants of RC circuits

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.
2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.
3. Graf, Rudolf F. Modern Dictionary of Electronics. 6th ed. Indianapolis, IN: Howard W. Sams & Co., Inc., 1984.
4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.
5. Schuler, Charles A.; Richard J. Fowler. Basic Electricity and Electronics. St. Louis: McGraw-Hill, 1988.

B. Curriculum guides

1. Hartman, Lonnie. Basic Electronics. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.
2. Robertson, L. Paul. Basic Electronics I. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1980.
3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. The use of aluminum foil and waxed paper in conjunction with a capacitance meter can graphically demonstrate the effects of plate area and plate distance on capacitance.

2. With the above method for making capacitors and the use of the capacitance meter, combinations of capacitors in series and parallel can also be graphically demonstrated.

B. Suggested supplemental materials

1. Bruce, David. Modern Electronic Basics, Devices and Applications. Reston, Va.: Reston Publishing Co., Inc., Prentice-Hall, 1984.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VII: ELECTROMAGNETICS AND ELECTROSTATICS

LESSON 1: MAGNETISM

NOTE: Power is generated by the interaction of magnetic and electrical forces. This lesson introduces magnetism. The understanding of this material is essential to understanding most of the complex circuits that a technician will encounter.

I. Terms and definitions

   A. Electromagnet--core of soft iron that is temporarily magnetized by sending current through a coil of wire wound around the core

   B. Electromagnetic induction--process of generating an electrical current and voltage by causing magnetic lines of flux to cut across an electrical conductor

   C. Flux--lines of force extending from north to south magnetic poles

   D. Henry--unit of inductance equal to one volt of EMF; developed when a change rate of one amp of current per second exists in a circuit

   E. Inductor (coil, choke)--component designed to introduce the property of inductance into an electrical circuit

   F. Magnetic field--area around a magnet through which the lines of force flow

   G. Magnetism--a property of certain materials which exerts a mechanical force on other materials and which can cause induced voltages in conductors when relative movement is present

   H. Mutual induction--process of one conductor inducing the voltage into another conductor

   I. Permeability (μ)--an indication of the relative ease with which magnetic lines of flux travel through a given material

   J. Permeance--reciprocal of reluctance

   K. Reluctance--a term for the opposition to the presence of magnetic flux

   L. Retentivity--ability of a material to retain magnetism

   M. Time constant--amount of time (in seconds) required for a reactor (capacitor or inductor) to change voltage by 63.2% of its difference compared to the applied voltage

II. Magnetism

   A. Classification of magnets (TM 1.1, 1.2)

      1. Natural magnets such as the earth or lodestones

      2. Artificial magnets formed by stroking a material with a natural magnet or by subjecting the material to a strong magnetic field

      3. Temporary or permanent depending upon the retentivity of the material of which they are made.

4. By the shape such as horseshoe, bar or ring

5. By the type of material used such as ceramic or metallic (aluminum, nickel, cobalt alloy or copper, nickel, iron alloy)

B. Characteristics of magnetic materials

1. Three natural elements--iron, cobalt and nickel--respond to magnetic fields.

2. Ferromagnetic substances readily respond to magnetism or magnetic fields.

3. Paramagnetic substances are attracted only slightly by a strong magnetic field.

4. Diamagnetic materials are substances which are slightly repelled by magnetic fields.

5. Relative permeability

   a. Less than unity for diamagnetic materials

   b. Slightly greater than unity for paramagnetic materials

   c. Much greater than unity for ferromagnetic materials

   NOTE: Permeability may be compared to conductance in a circuit.

C. Characteristics of magnetic flux lines (HO 1.1)

1. Magnets are surrounded by a force field made up of flux lines.

2. Flux lines have both direction and polarity.

3. Magnetic lines of force are assumed to exit from the north pole of a magnet and return through the surrounding space to enter the south pole of the magnet.

4. The magnetic lines of force surrounding a magnet form complete loops.

5. Flux lines do not cross each other.

   NOTE: Like poles repel each other.

6. Flux lines will tend to restrict themselves to the smallest possible loops.

   NOTE: Unlike poles attract each other.

D. Magnetic quantities (HO 1.1)

1. Flux (phi or Φ)--complete magnetic field surrounding a magnet

2. Flux density (B)--number of lines of flux per unit area

3. Magnetomotive force (mmf)--force which produces flux in an electromagnet or coil (measured in ampere-turns)

4. Field intensity or magnetizing force (H)--both mmf and the length of the coil (expressed as ampere-turns per inch)

5. Permeability (μ)--ease with which a material can accept lines of force

NOTE: Permeability may also be thought of as the ability of a material to concentrate lines of force.

6. Reluctance (R)--the opposition to flux and the reciprocal of permeability

7. Ohm's law for magnetism--The magnetic flux developed in a core material is directly proportional to the magnetomotive force and inversely proportional to the reluctance. This can be expressed as:

$$\text{phi } (\Phi) = \frac{\text{mmf}}{\text{R}}$$

III. Relationship of magnetism to electricity

A. When current flows through a wire, a magnetic field is produced around the wire. (TM 1.3)

1. The direction of the field is determined by the direction of electron flow.

2. The left-hand rule for conductors may be used to determine the direction of the lines of flux. (HO 1.2)

a. Grasp the conductor with the left hand with the thumb pointing in the direction of electron flow.

b. The direction in which the four fingers are pointing is the direction of the magnetic field.

B. The field surrounding a conductor may be strengthened by forming the conductor into a coil.

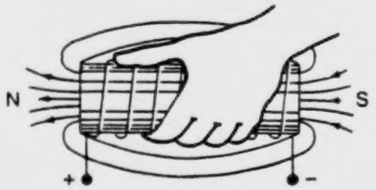
C. Fundamentals of electromagnetism

1. The strength of the magnetic field around a coil is directly proportional to both the number of turns in the coil and the amount of current through the coil.

2. The strength of the electromagnetic field may be dramatically strengthened by placing a core of ferromagnetic material inside the coil.

3. The polarity of the electromagnetic field may be determined by the left-hand rule for electromagnets. (HO 1.2)

a. Grasp the coil with your left hand in such a way that your fingers encircle the coil in the same direction as the current is flowing. (See figure below.)



b. Your thumb will point in the direction of the north pole of the electromagnet.

D. Principles of induction (TM 1.4, 1.5)

1. Magnetic induction occurs when a magnet is placed in close proximity to a ferromagnetic material causing the material to also become magnetized.

2. Electromagnetic induction is the action which causes electrons to flow in a conductor when the conductor cuts the lines of force in a magnetic field.

3. The amount of current induced into the conductor is determined by four factors (Faraday's law):

   a. Strength of the magnetic field

   b. Speed of the conductor with respect to the field

   c. Angle at which the conductor cuts the field

   d. Length of the conductor in the field

4. Lenz's law--The direction of the induced current must be such that its own magnetic field will oppose the action that produced the induced current.

E. Generating voltage by electromagnetic induction (TM 1.6)

1. There are three basic requirements for generating voltage electromagnetically:

   a. A magnetic field

   b. A conductor in the magnetic field

   c. Relative motion between the conductor and the magnetic field

2. The direction of the voltage generated by electromagnetic induction is determined by the direction of motion and the direction of magnetic flux.

3. When a conductor, shaped in a loop, is rotated in a magnetic field, a sinusoidal alternating voltage wave-form is produced. (HO 1.3)

4. The left-hand generator rule may be used to determine the direction of emf and the resulting electron flow. (HO 1.3)

5. The magnitude of the induced voltage is proportional to the number of flux lines cut by the conductor per second.

6. The number of flux lines cut per second by the conductor is determined by four factors:

   a. The velocity of the conductor

   b. The strength of the magnetic field

   c. The length of the conductor

   d. The angle at which the conductor cuts the field

   NOTE: When the conductor moves parallel to the lines of force, no voltage is generated; when the conductor moves at right angles to the lines, maximum voltage is generated.

F. Characteristics of self-induction (HO 1.4)

1. When current begins to flow in a wire or coil, a sequence of events occurs and produces self-induction.

        a. The switch is closed.

        b. Current starts to flow in the wire.

        c. A magnetic field begins to form around the wire.

        d. The moving magnetic field being formed induces a voltage back into the wire.

    2. The induced current caused by self-induction is counter to the original current.

       NOTE: The induced current is called counter EMF (CEMF).

    3. Self-induction occurs both when current is increasing in a circuit and when current is decreasing in a circuit.

    4. The effect of self-induction or counter EMF is to oppose changes in current flow.

G. Characteristics of inductance

    1. Inductance is the physical property of a circuit or device which indicates an ability to oppose a change in current.

    2. Inductance may also be defined as the ability to induce an EMF into a conductor when there is a change in current flow.

    3. The symbol for inductance is the letter L.

    4. The unit of measurement for inductance is the henry.

        a. henry--amount of inductance that induces an EMF of one volt into a conductor when the current changes at the rate of one ampere per second

        b. The henry is expressed symbolically with the letter "H".

       NOTE: The henry is a relatively large unit. Therefore, the milli-henry (mH) and the micro-henry (μH) are the units generally used in practice.

H. Factors affecting inductors

    1. An inductor is a physical device consisting of a coil of wire usually wound on a core.

       NOTE: An inductor may also be called a coil or choke.

    2. The inductance of a coil varies as the square of the number of turns.

    3. Inductance of a coil may be increased dramatically by winding the coil on a core of material that has a high permeability.

    4. Inductance varies inversely with the length of the coil.

I. Time constants of inductive circuits (HO 1.5)

    1. The time required for current to fall or rise in a circuit is called the time constant.

    2. A time constant of an inductor is the time required for the current to rise to 63.2% of its maximum possible value or decrease by 63.2% of its maximum value. (TM 1.7)

    3. The inductive time constant in a circuit is a function of both inductance and resistance.

    a. The time constant is directly proportional to the inductance and inversely proportional to the resistance.

    b. The relationship of time constant, resistance and inductance is expressed by the formula $T = L \div R$.

IV. Connecting inductors in series and parallel

  A. The rules for connecting inductors in series and parallel are similar to those used with resistors.

  B. For two or more inductors connected in series, the total inductance is the sum of the inductances when no mutual inductance exists ($L_T = L_1 + L_2 + L_3 + \ldots$).

  C. When mutual inductance is present and the magnetic fields are aiding, the total inductance of two or more inductors in series may be expressed by the formula $L_T = L_1 + L_2 + 2Lm$.

  D. When two inductors are connected in series, the magnetic fields opposing the total inductance of the combination may be found with the formula $L_T = L_1 + L_2 - 2Lm$.

  E. When two inductors are connected in parallel, the total inductance may be found with the formula:

$$L_T = \frac{L_1 \times L_2}{L_1 + L_2}$$

  NOTE: The reciprocal formula used to find resistors in parallel may also be applied to inductors in parallel.

V. Power characteristics in an inductive circuit (TM 1.8)

  A. No power is dissipated in a pure inductance.

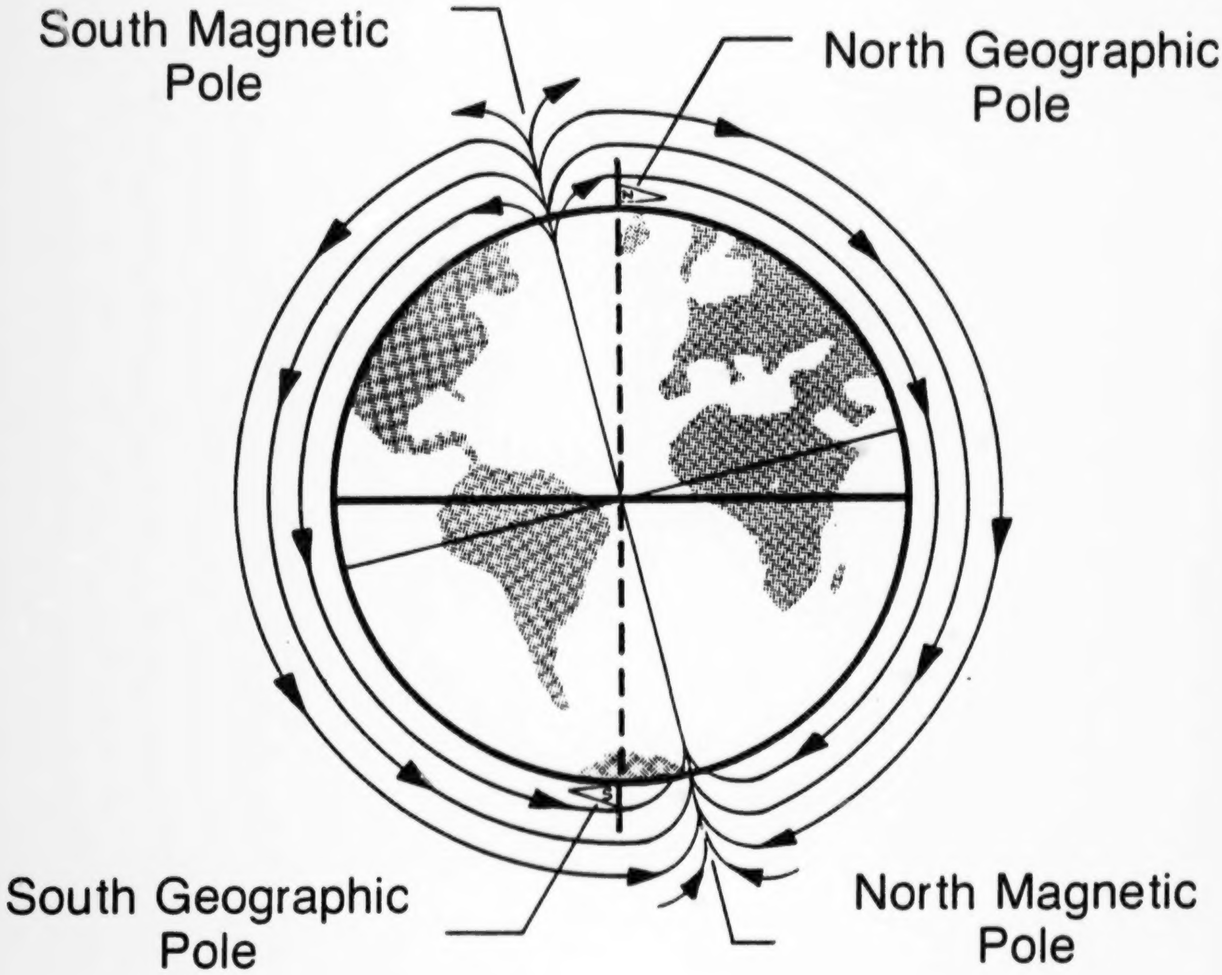
  NOTE: We are unable to make totally pure inductors and therefore all inductors have some resistance within the wire of which they are made.

  B. Power dissipation in an RL circuit occurs in the resistance within the circuit.

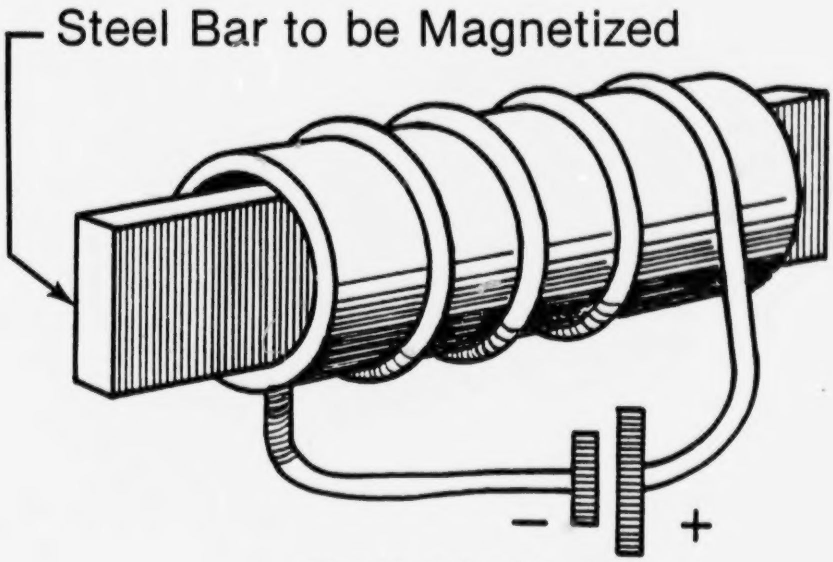
  C. Since power is dissipated only in the resistance, it may be calculated using the standard power formulas:

$P = EI$ $P = I^2R$ $P = E^2 \div R$

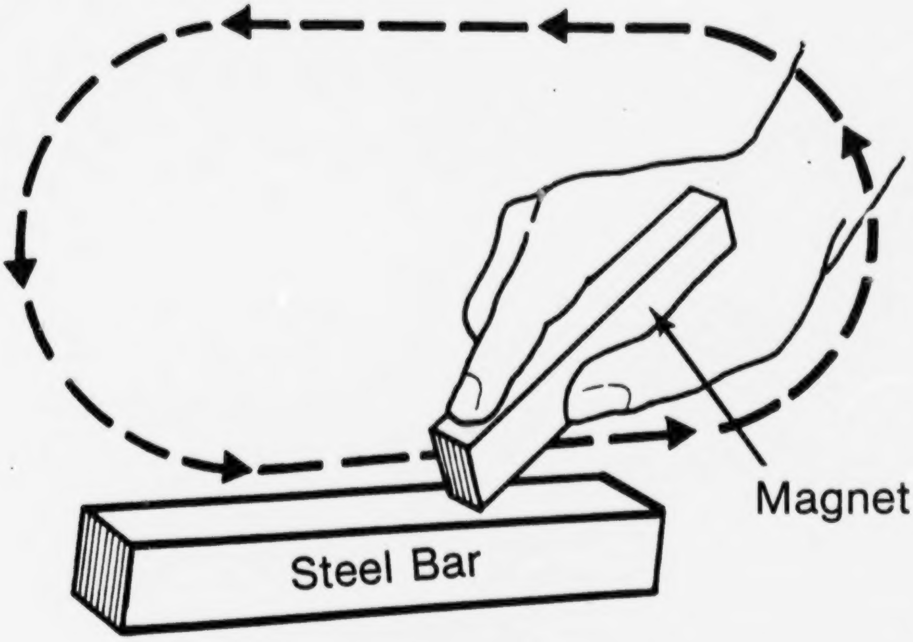
MAGNETIC POLES


South Magnetic Pole
North Geographic Pole
N
S
South Geographic Pole
North Magnetic Pole

PRODUCING ARTIFICIAL MAGNETS

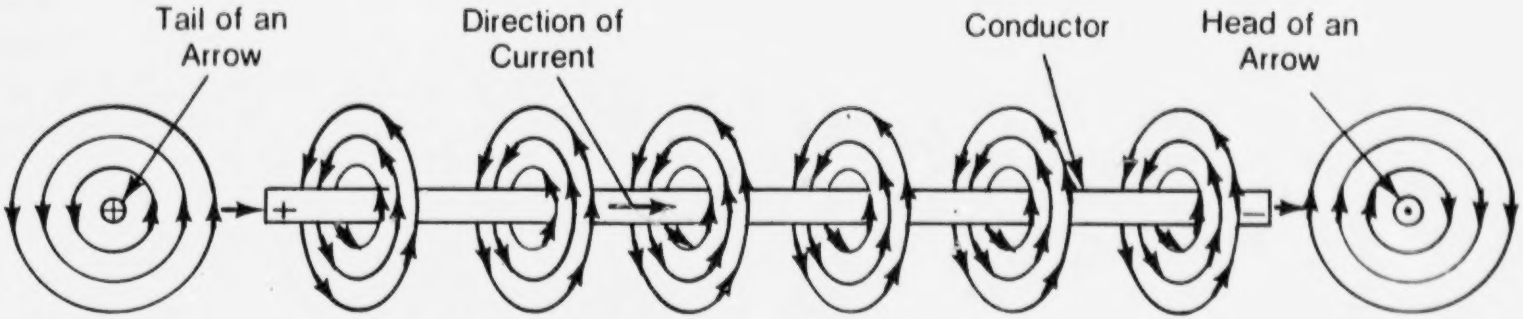

Steel Bar to be Magnetized
−
+

Coil Method


Magnet
Steel Bar

Stroking Method

MAGNETIC FIELD
AROUND A CURRENT-CARRYING CONDUCTOR


Tail of an Arrow
Direction of Current
Conductor
Head of an Arrow
+
−

① Cross-Section of Conductor and Magnetic Field

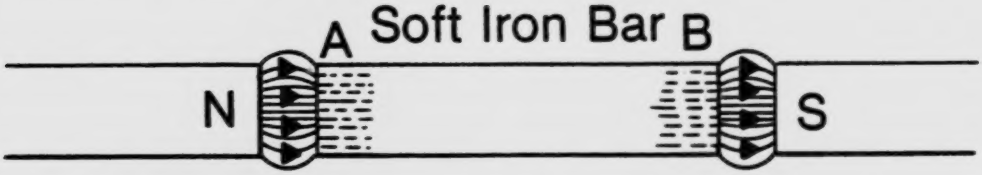
② Magnetic Field About a Conductor

③ Cross-Section of Conductor and Magnetic Field

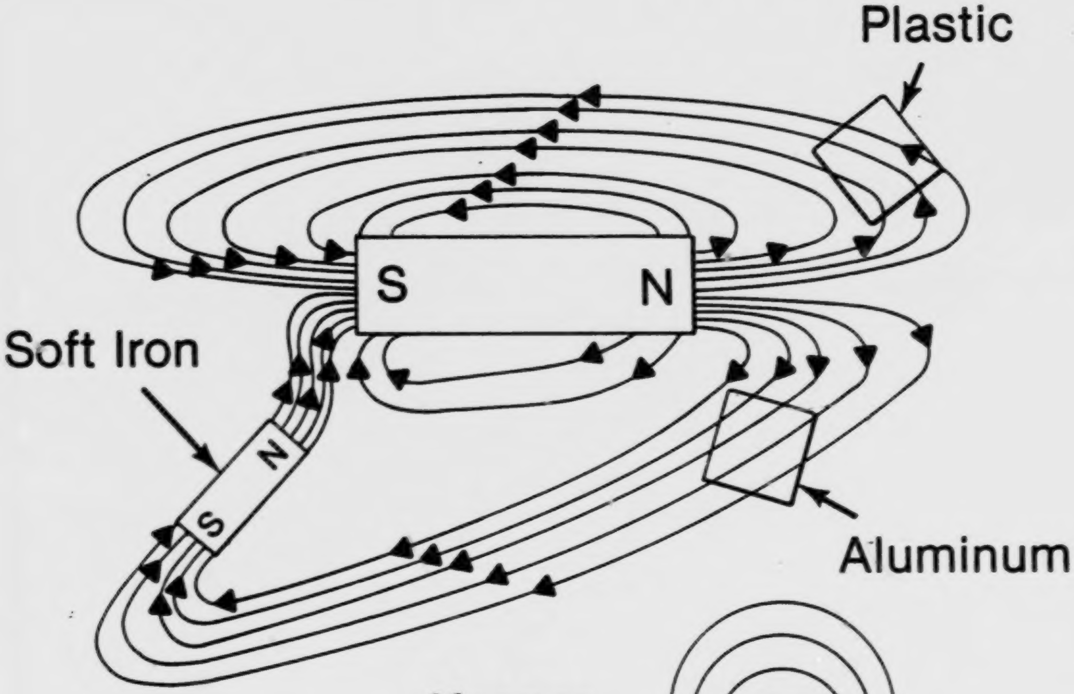
217

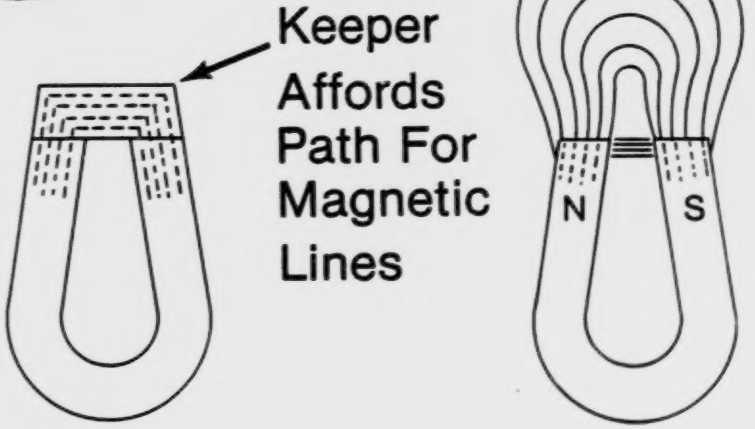
218

CONCENTRATION OF LINES OF FLUX

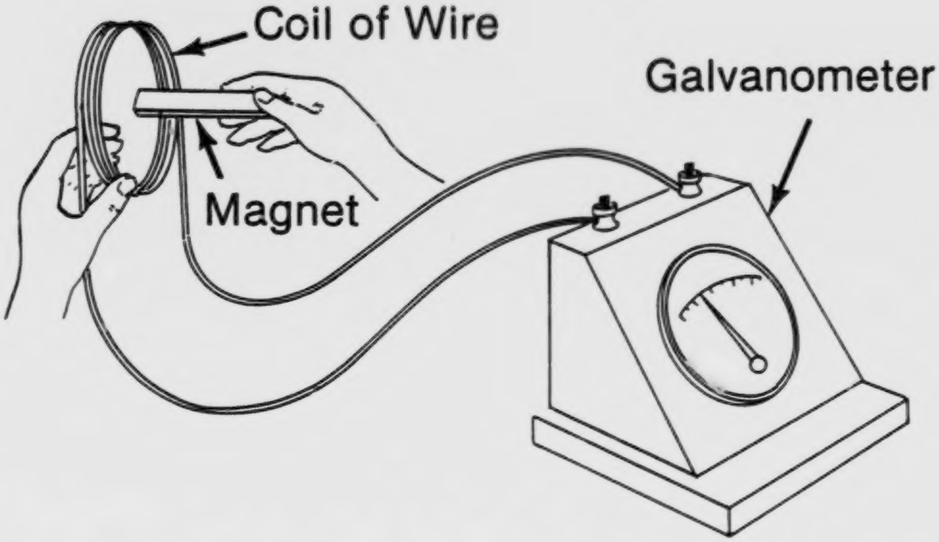

A
Soft Iron Bar
B
N
S

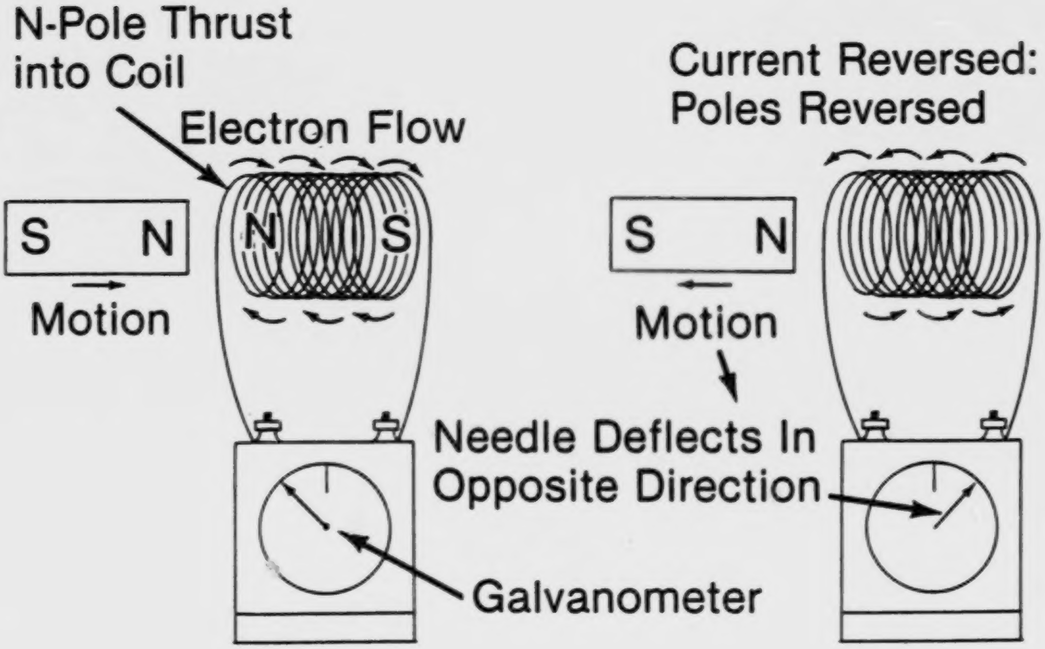
Magnetizing an Iron Bar by Induction


Plastic
S
N
Soft Iron
N
S
Aluminum

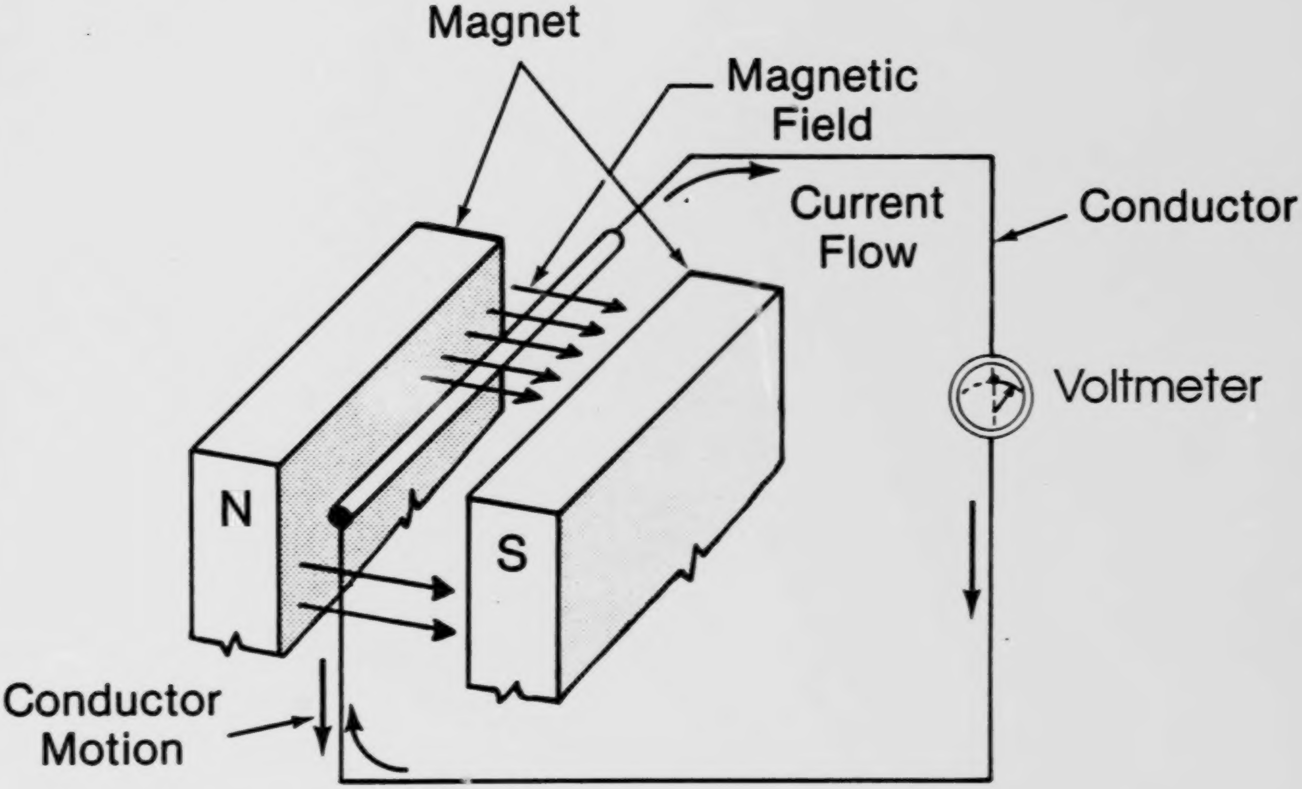

Keeper
Affords
Path For
Magnetic
Lines
N
S

INDUCED CURRENT

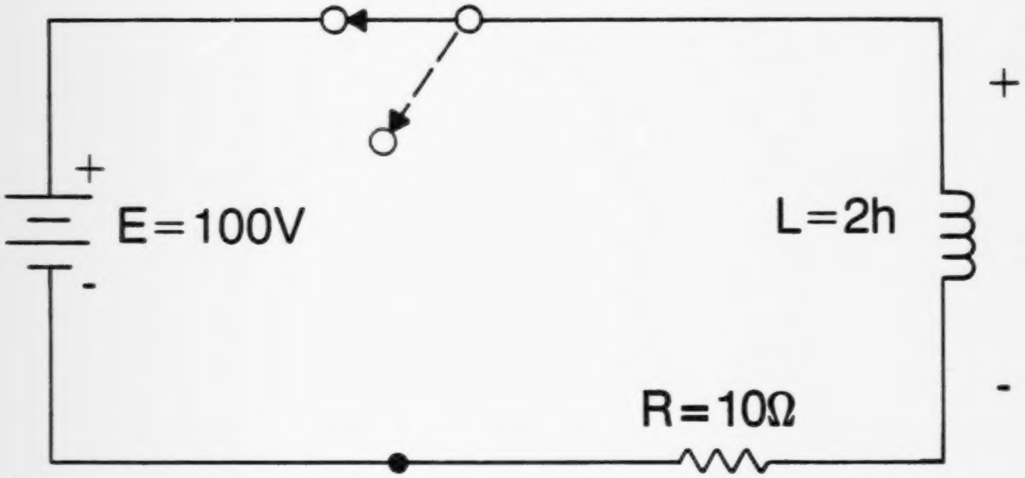

Coil of Wire
Galvanometer
Magnet

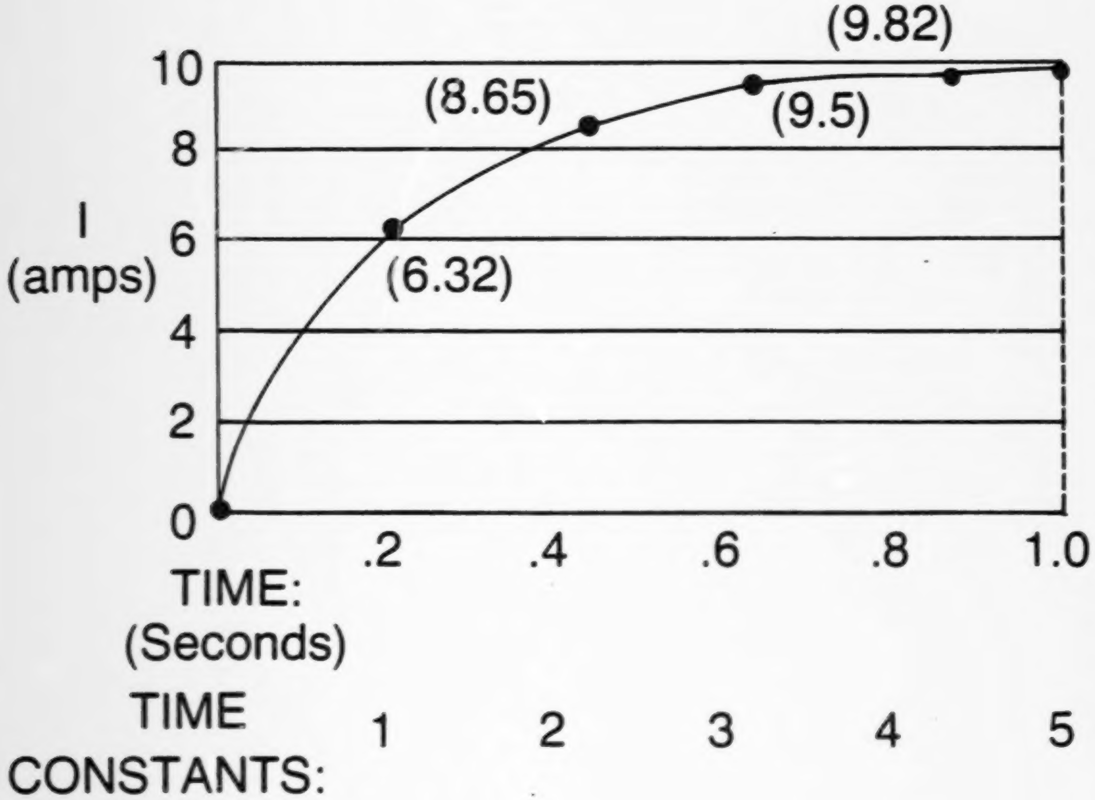

N-Pole Thrust into Coil
Electron Flow
S
N
N
S
Motion
Current Reversed: Poles Reversed
S
N
Motion
Needle Deflects In Opposite Direction
Galvanometer

ELECTROMAGNETIC INDUCTION

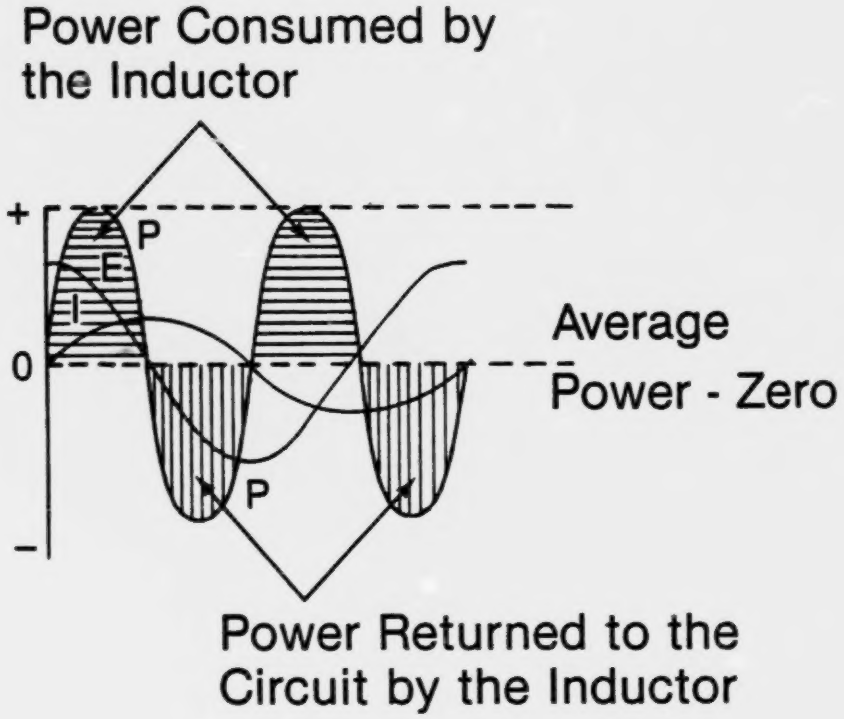

Magnet
Magnetic Field
Current Flow
Conductor
Voltmeter
N
S
Conductor Motion

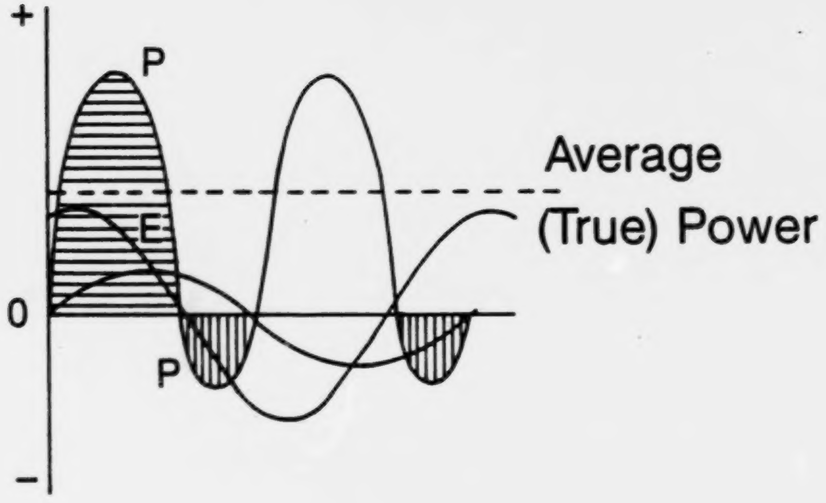
RL CIRCUIT AND CURRENT RISE


+
-
E=100V
L=2h
+
-
R=10Ω

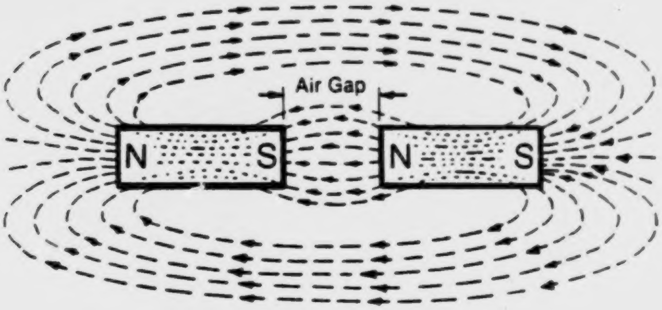


POWER IN RL CIRCUITS

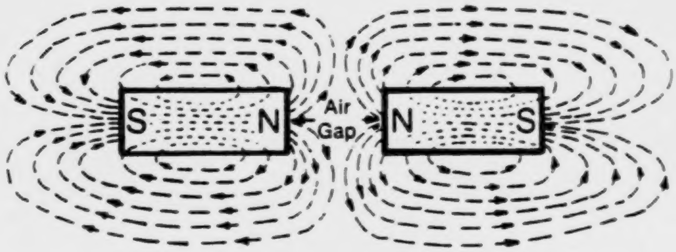

Power Consumed by the Inductor
+
P
E
I
0
Average Power - Zero
P
–
Power Returned to the Circuit by the Inductor


+
P
Average (True) Power
E
0
P
–

MAGNETIC LINES OF FORCE, FLUX AND FLUX DENSITY

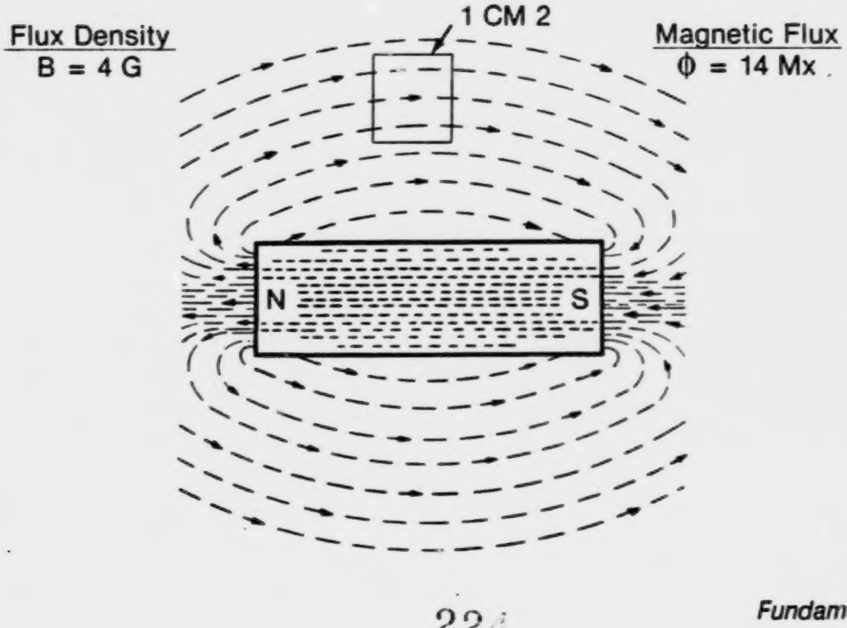

Air Gap
N
S
N
S

Unlike Poles Attract

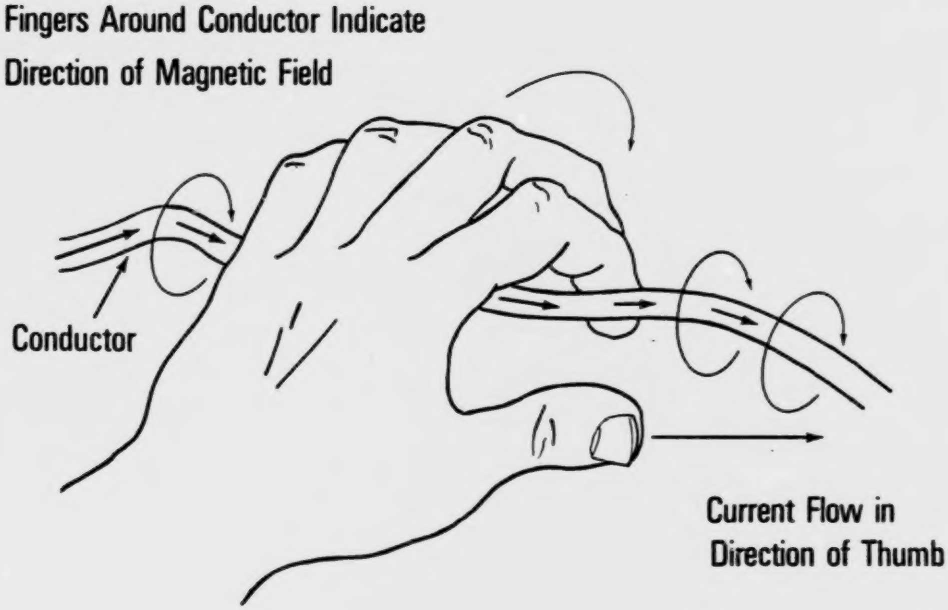

S
N
Air Gap
N
S

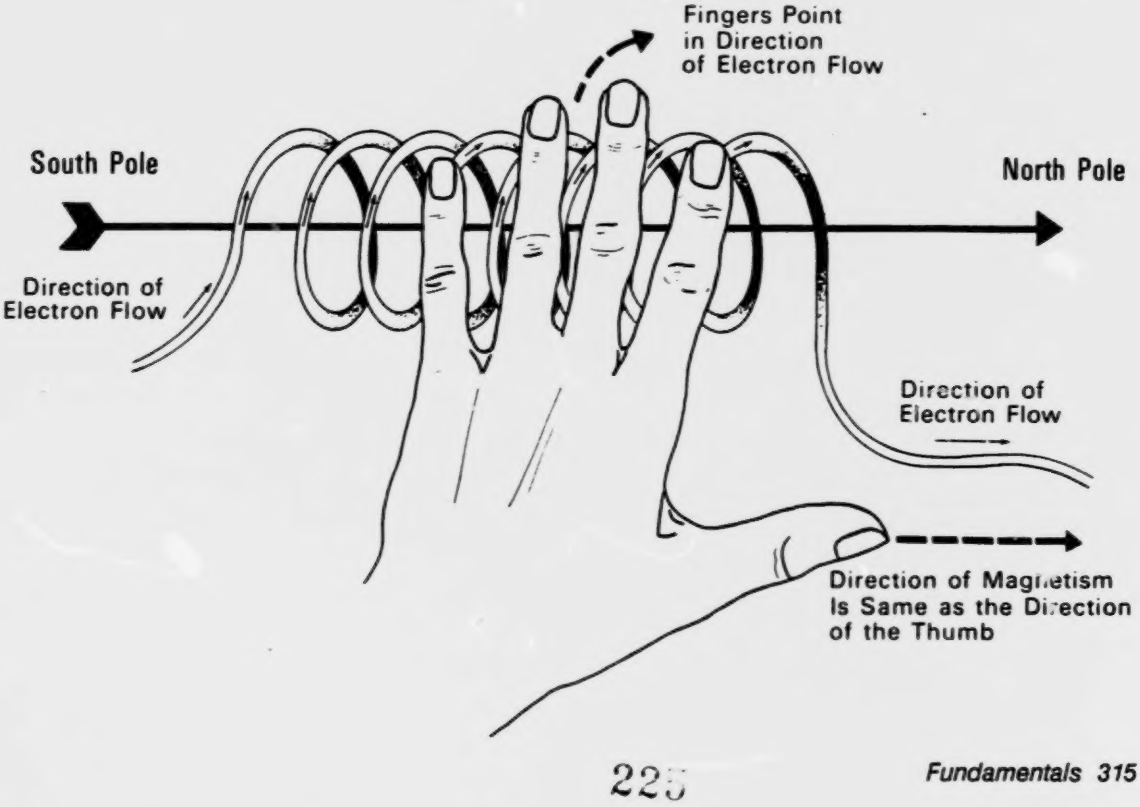
Lines of Force

Like Poles Repel

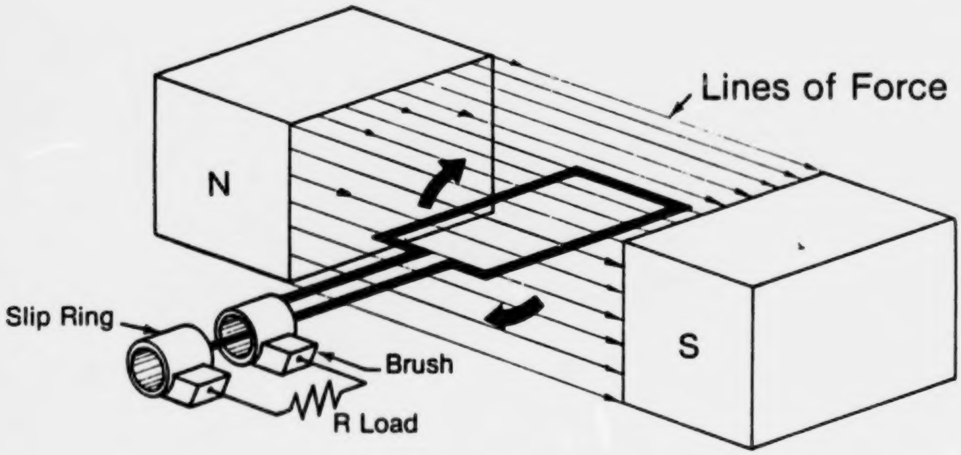

Flux Density
B = 4 G
1 CM 2
Magnetic Flux
Φ = 14 Mx
N
S

LEFT-HAND RULE FOR MAGNETIC LINES OF FLUX AND ELECTROMAGNETS

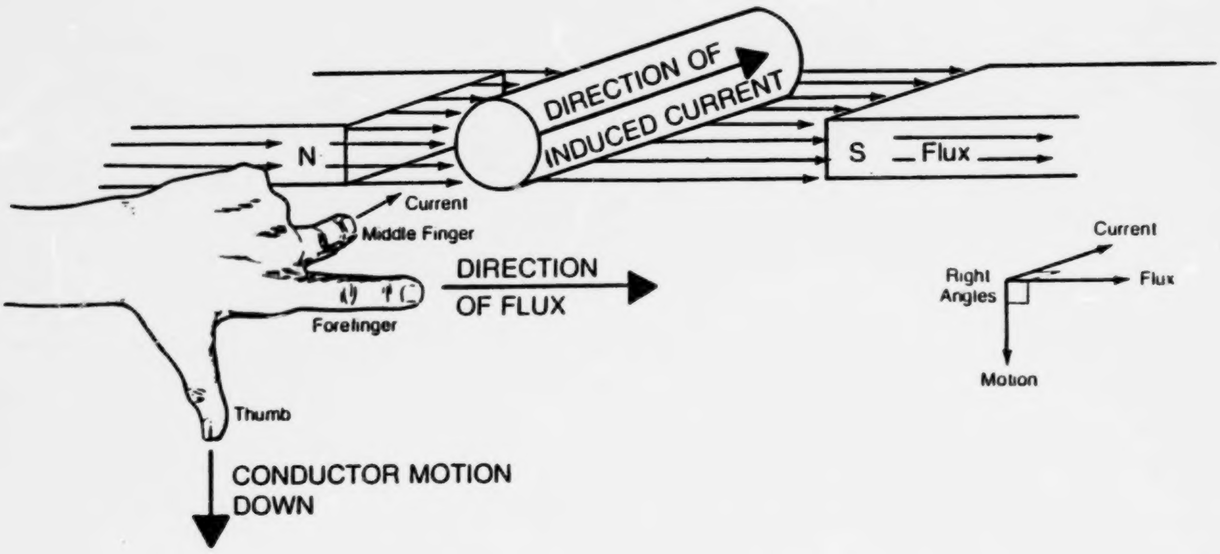

Fingers Around Conductor Indicate
Direction of Magnetic Field
Conductor
Current Flow in
Direction of Thumb


Fingers Point
in Direction
of Electron Flow
South Pole
North Pole
Direction of
Electron Flow
Direction of
Electron Flow
Direction of Magnetism
Is Same as the Direction
of the Thumb

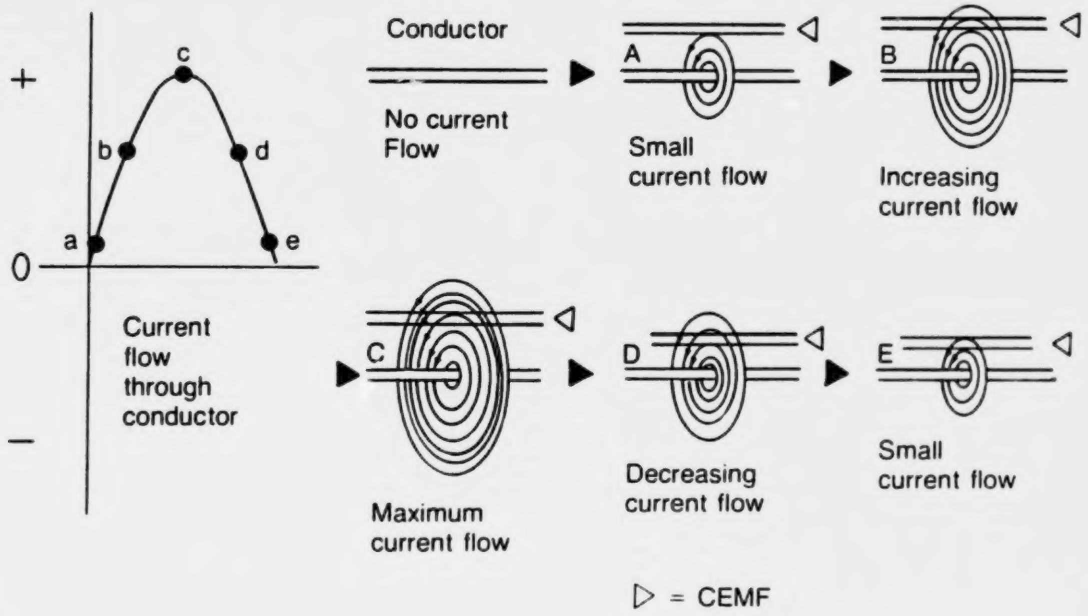
SIMPLE AC GENERATOR AND . . .


Lines of Force
N
S
Slip Ring
Brush
R Load

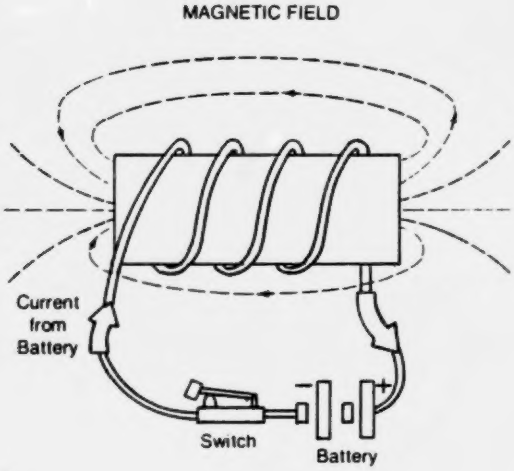
THE LEFT-HAND GENERATOR RULE


DIRECTION OF INDUCED CURRENT
N
S
Flux
Current
Middle Finger
DIRECTION OF FLUX
Forefinger
Thumb
CONDUCTOR MOTION DOWN
Current
Right Angles
Flux
Motion

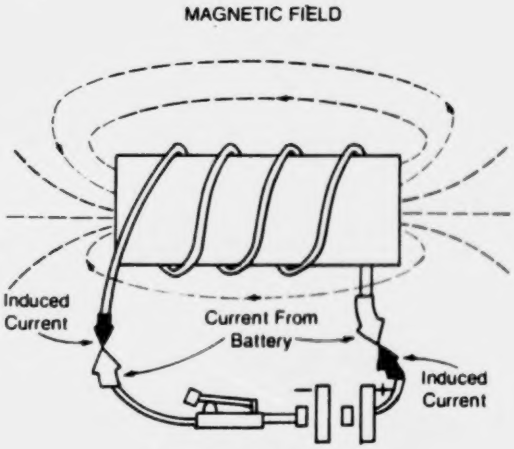
CONCENTRATION OF LINES OF FLUX


+
c
b
d
a
e
0
Current flow through conductor
–
Conductor
No current Flow
A
Small current flow
B
Increasing current flow
C
Maximum current flow
D
Decreasing current flow
E
Small current flow
▷ = CEMF

Relationship of magnetic field around a wire to current flowing through the wire.

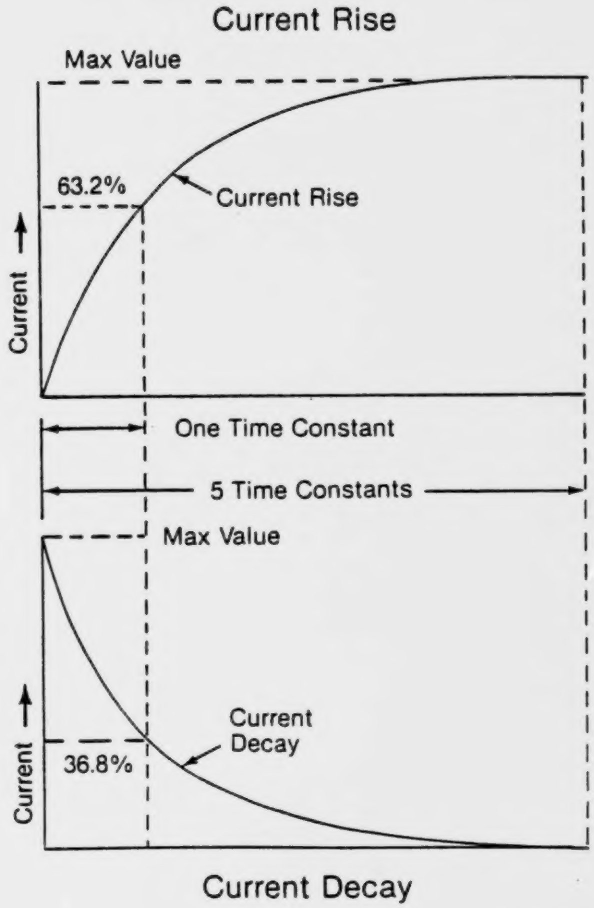

MAGNETIC FIELD
Current from Battery
Switch
Battery
–
+

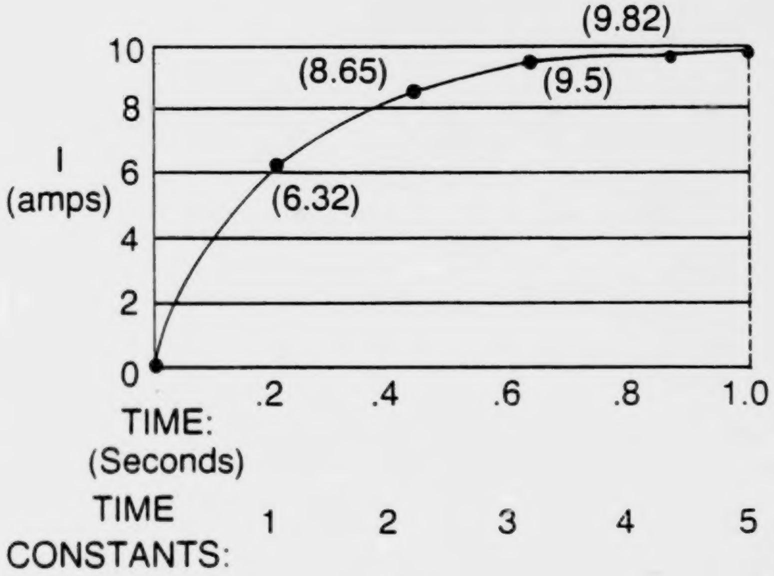
A. Current Creates Magnetic Field


MAGNETIC FIELD
Induced Current
Current From Battery
Induced Current

B. Magnetic Field Induces Opposing Current

CURRENT RISE AND DECAY IN AN INDUCTOR


Current Rise
Max Value
63.2%
Current Rise
Current
One Time Constant
5 Time Constants
Max Value
Current
Decay
36.8%
Current
Current Decay



AS 1.1

CURRENT FLOW DIRECTION AND INDUCTION

Place a T before true statement and an F before false ones.

____ 1. Moving a conductor which cuts the lines of a magnetic field induces a voltage in the conductor.

____ 2. EMF is generated when the magnetic field is moved and the conductor is stationary (assuming that lines of flux are being cut).

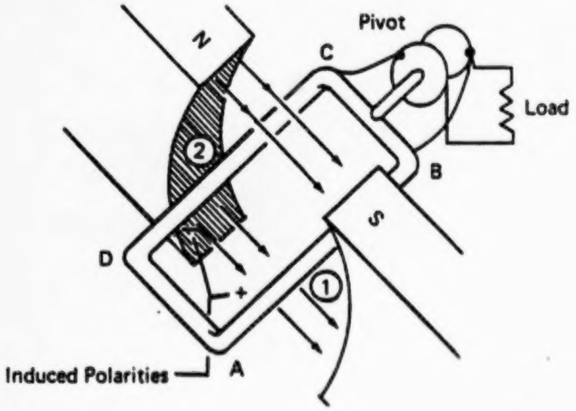
____ 3. Use the left-hand generator rule to determine electron displacement.

____ 4. When using the left-hand generator rule, the ring finger corresponds with the direction of conductor motion.

____ 5. The forefinger indicates the direction of magnetic flux lines (left-hand generator rule).

____ 6. When using the left-hand generator rule, the thumb corresponds with the direction of current flow.

Study the illustration below and answer the following questions.



____ 7. When leg #1 is moving downward, from which letter position will current move out of the loop into the circuit?

____ 8. When leg #2 moves downward, current will flow (from-to) __________ in leg #1.

____ 9. When leg #2 moves upward, current flows (from-to) _________ in leg #2.

____ 10. When leg #2 arrives at the same position as leg #1, what happens to the current?

a. Reverses direction
b. Continues in the same direction
c. Shorts out

Indicate whether the *source current* is increased (I) or decreased (D) for each of the following.

____ 11. Inductance and induced EMF source current

____ 12. Inductance and induced EMF sustain source current

Indicate whether **inductance** increases (I) or decreases (D) as a result of each of the four actions that follow.

____ 13. Decrease core permeability

____ 14. Add turns to a coil

____ 15. Increase the cross-sectional area of the core

____ 16. Decrease the length of the core

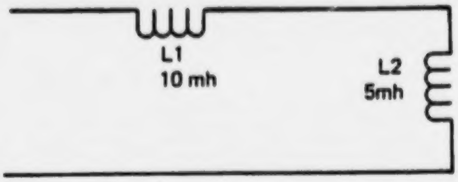
____ 17. Which correctly finishes the statement, "When the switch is suddenly opened in an inductive circuit, __________."

a. The magnetic field around the coil begins to collapse
b. Current tries to continue to flow due to induced voltage
c. Current decays rather than abruptly going to zero
d. None of the above

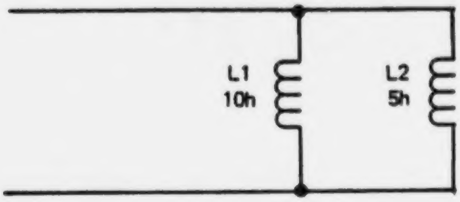
18. What is another name for induced voltage? ____________________________

TOTAL INDUCTANCE AND TIME CONSTANTS

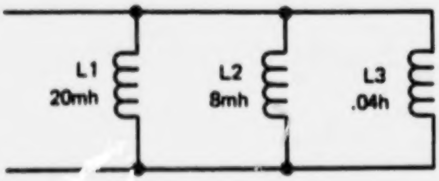
1. Find L_T in this circuit (assume no mutual inductance). __________


L1
10 mh
L2
5mh

2. Solve for L_T. __________



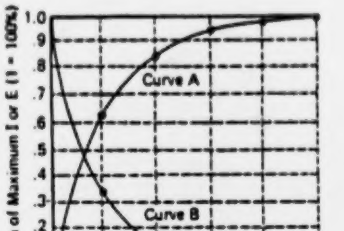
3. Solve for L_T. __________


L1
20mh
L2
8mh
L3
.04h

4. In a series RL circuit, which curve on the universal time-constant chart shows:

   a. Percent current increase? _____

   b. Percent current decrease? _____



5. According to the previous chart, how many time constants are required for:

   a. Current to rise to maximum value? ________

   b. Current to decay from maximum to zero? ________

6. For Curve A, what is the percentage of current increase (rise) at:

   a. 1TC? _____

   b. 2TC? _____

   c. 3TC? _____

   d. 4TC? _____

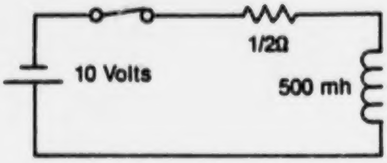
7. When the switch is turned off and current starts to decay, it will have dropped to what percentage of its maximum value (percent decay) at:

   a. 1TC? _____

   b. 2TC? _____

   c. 3TC? _____

Fill in the blanks in the following statements using the circuit below and the universal time-constant chart.



8. The maximum current that will flow in the circuit is _______ amps.

9. The time at one time constant is ____________.

10. The time required to reach the maximum current after switch closure is ______________.

11. The time required to reach 19 amperes is _________ seconds after switch closure.

ANSWERS TO AS 1.1

1. T
2. T
3. T
4. F
5. T
6. F
7. B
8. B to A
9. D to C
10. a
11. I
12. D
13. D
14. I
15. I
16. I
17. a, b, c
18. CEMF

ANSWERS TO AS 1.2

1. 15mh
2. 3.33mh
3. 5mh
4. a. A
   b. B
5. a. 5
   b. 5
6. a. 63.2%
   b. 86.5%
   c. 95%
   d. 98%
7. a. 36.8%
   b. 13.5%
   c. 5%
8. 20
9. 1 second
10. 5 seconds
11. 3

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VII: ELECTROMAGNETICS AND ELECTROSTATICS

LESSON 2: ELECTROSTATIC DEVICES (CAPACITORS)

NOTE: Many products depend on the "electrostatic" effect of electricity to function properly. Examples of these products include copy machines, radios, TVs, satellite receivers, tape recorders, optical disc players and computers. An electronics technician must know basic information about capacitors in order to repair these devices.

I. Terms and definitions

   A. Capacitance--ability of a capacitor to store charge (a quantity of electrons)

   B. Capacitor--device that stores electrical energy as an electrostatic charge in the dielectric (insulator) that exists between two conductive materials (plates)

   C. Dielectric--insulating material in a capacitor

   D. Electrostatic--relates to the interaction of charges in which like charges repel each other and unlike charges attract each other (example: static electricity)

   E. Farad--the unit of measurement of capacitance which is the ability to store one Coulomb of electrons when one volt of electrical force is applied

   F. Time constant--amount of time (in seconds) required for a reactor (capacitor or inductor) to change voltage by 63.2% of its difference compared to the applied voltage

II. Characteristics of capacitance

   A. Capacitance--property of a circuit or device which enables it to store electrical energy with an electrostatic field (TM 2.1)

   B. Capacitor--device that is made to have a specific value of capacitance

      1. The number of electrons that a capacitor can store for a given applied voltage is a measure of its capacitance.

      2. A capacitor has the ability to store electrons and discharge them at a later time.

   C. A capacitor is a device constructed of two metal plates separated by a dielectric.

   D. A capacitor's capacitance is determined by three factors.

      1. The area of the metal plates (HO 2.1)

      2. The spacing between the plates

3. The type or nature of the dielectric

Typical dielectrics

Type	Constant	Breakdown
Air	1.0	---
Mica	5.4	5000V/mil
Teflon	2.1	1500V/mil
Paper	3.0	200V/mil

E. The unit of capacitance is the farad (F).

F. One farad is the amount of capacitance which will store a charge of one coulomb when one volt of EMF is applied.

NOTE: The farad is a very large unit and therefore is commonly expressed in terms of micro-farads or pico-farads.

G. Capacitance may be expressed in terms of charge and voltage by the formula $C = Q \div E$. (C is the capacitance; Q is the quantity of electrical charge in coulombs and E is the applied voltage.)

III. Types, ratings and common defects of capacitors

A. Capacitor classification methods

1. By type (fixed or variable)

2. By dielectric

a. Mica

b. Ceramic

c. Paper

d. Metalized film

e. Mylar

f. Electrolytic (polarized)

g. Tantalum (polarized)

B. Markings on capacitors (All capacitors do not necessarily have all markings.)

1. Positive or negative markings if polarized

2. Voltage markings in working volts DC (WVDC)

3. Value of capacitance

a. Most capacitors have the value printed on the package.

b. IEC code work is similar to the resistor color code (the value is in pico-farads): first digit, second digit, a multiplier and a tolerance code

(M = 20%, K = 10%, J = 5%, C = ±0.25pF)

c. With electrolytic capacitors, the whole numbers are in micro-farads.

d. With ceramic capacitors, the whole numbers are in pico-farads.

e. Fractional values are in micro-farads.

f. The letter m (upper or lower case) always indicates micro when used on capacitors.

C. Defects in capacitors

1. Shorts if the dielectric is punctured or otherwise fails

2. Opens when one or both leads become disconnected

3. Excessive leakage between the plates

4. The capacitor may change in value due to manufacturing defect, too high a temperature or too much applied voltage.

IV. Combining capacitors in series and parallel

A. When two or more capacitors are connected in parallel, the total capacitance is the sum of that of the individual capacitors.

$C_T = C_1 + C_2 + C_3 + \ldots$

NOTE: This is in contrast to that of inductors or resistors in parallel.

B. The total capacitance of a parallel combination is always greater than any single value in the combination.

C. The formula for finding total capacitance of a series network is:

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

NOTE: The reciprocal formula can be used for multiple capacitors in series.

D. When two or more capacitors are connected in series, the total capacitance of the combination is less than the capacitance of the smallest capacitor.

V. Determining time constants in an RC circuit (TM 2.2)

A. Two factors determine charge and discharge time of an RC circuit.

1. Value of the capacitor

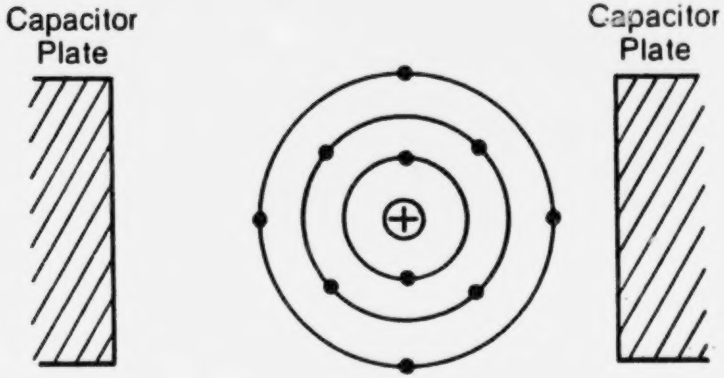
2. Value of the resistance in the charge/discharge path

B. One time constant is the time required for a capacitor to charge to 63.2% of the applied voltage or the time required for the voltage across the capacitor to discharge by 63.2%.

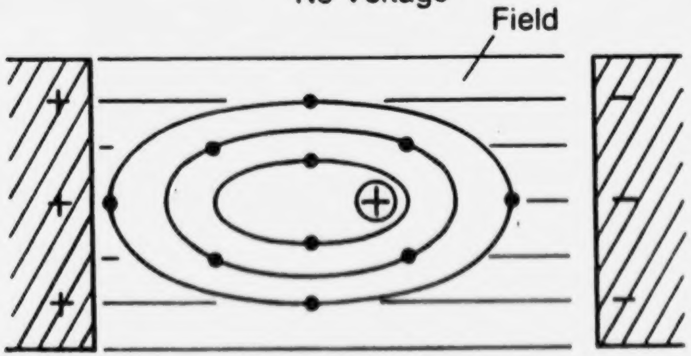
C. The time constant is expressed in the equation, $T = R \times C$, in which T is the time in seconds required to reach 63.2% of full charge, R is the resistance in ohms and C is the capacitance in farads.

CAPACITOR CONSTRUCTION AND ELECTRIC FIELD EFFECT ON DIELECTRICS

Electric Field Effect on Dielectrics


Capacitor Plate
Capacitor Plate

No Voltage



Voltage Applied

Capacitor Construction

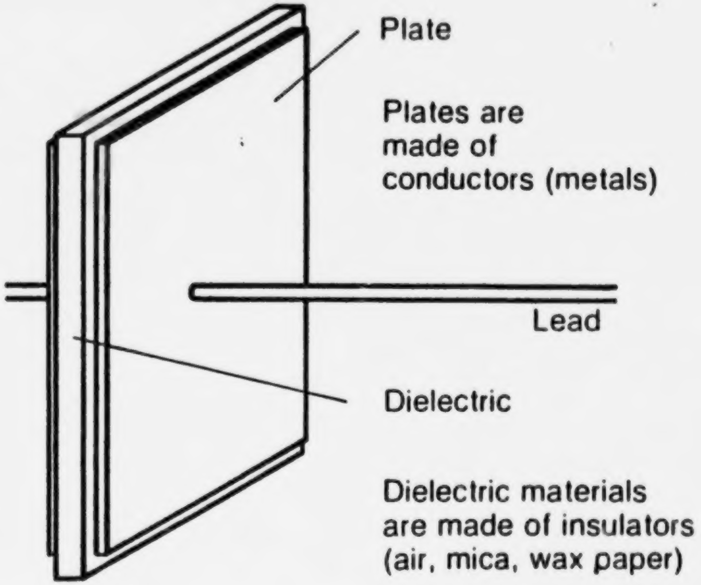


Plate
Lead
Dielectric

Plates are
made of
conductors (metals)

Dielectric materials
are made of insulators
(air, mica, wax paper)

UNIVERSAL TIME CONSTANT CHART FOR RC AND RL CIRCUITS

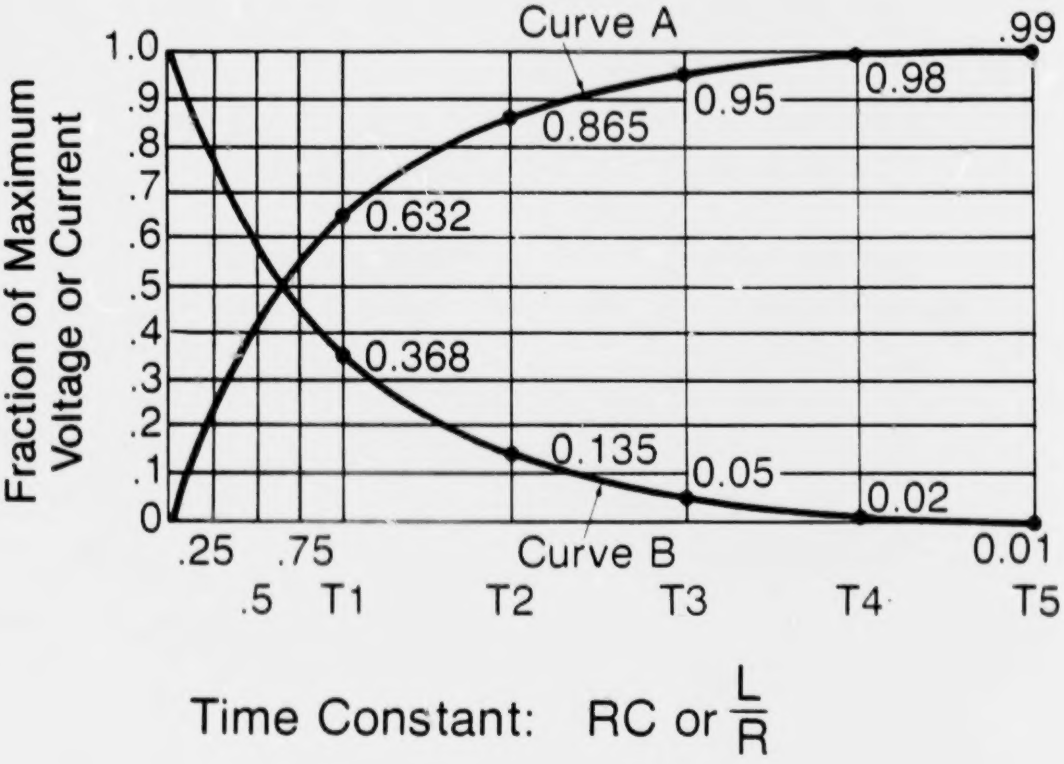
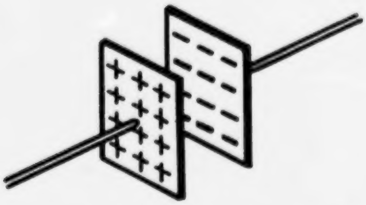
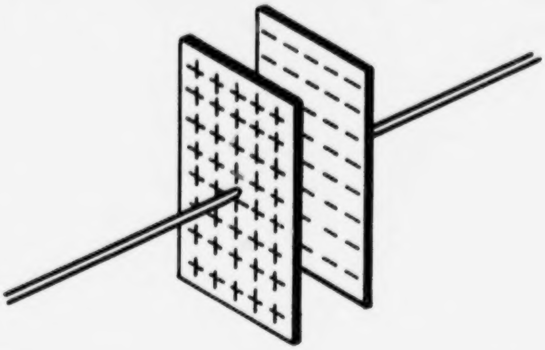


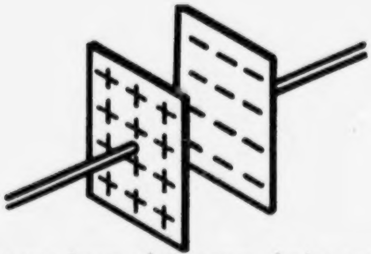
PLATE AREA AND PLATE DISTANCE



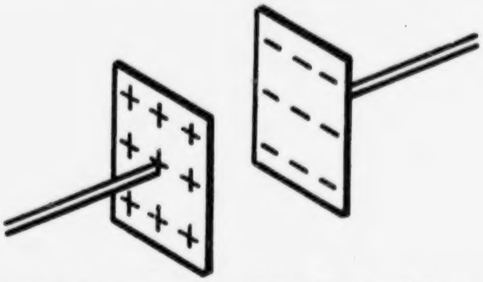
Larger plates hold more electrons.



Increased plate area increases capacitance.

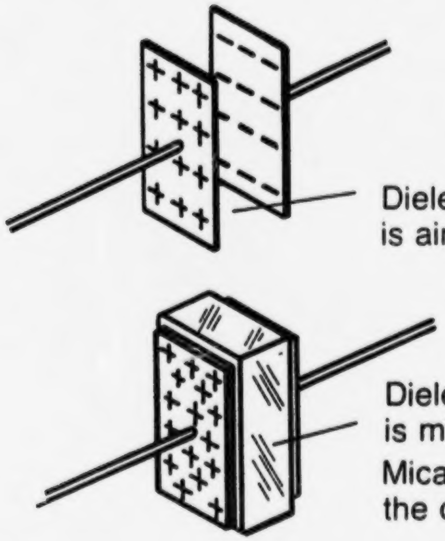


The distance between two charges determines their effect on one another.



Increasing the distance between the plates decreases capacitance.

EFFECT OF THE DIELECTRIC ON CAPACITANCE


Dielectrical material is air.
Dielectrical material is mica.
Mica dielectric increases the capacitance.

Changing the dielectric material changes the capacitance.

TOTAL CAPACITANCE VALUES

1. Write the formula showing the relationship between farads, volts and electric charge (or quantity).

2. Compute the amount of charge that will appear on the plates when 50 volts is applied to the following capacitors.

   a. 2F = ____________ coulombs

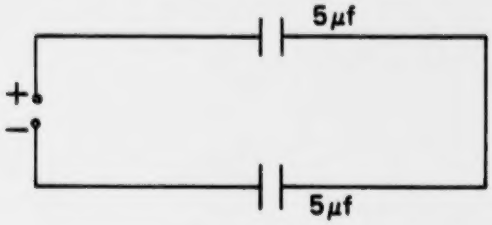
   b. 2μF = ____________ coulombs

   c. 2pF = ____________ coulombs

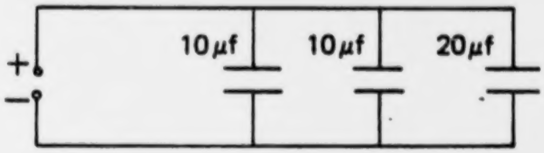
   d. 100μF = ____________ coulombs

3. Determine the total capacitance for each of the following circuits.

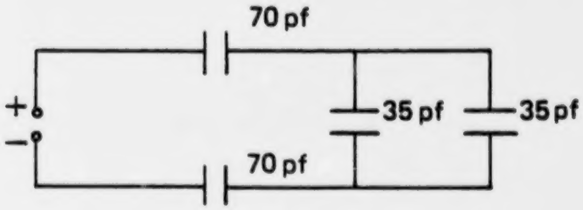
   a. C_T = ____________



   b. C_T = ____________



   c. C_T = ____________



RC TIME CONSTANTS

1. Write the formula for computing one time constant in an RC circuit.

Do the phrases below describe the rising curve (A) or the falling curve (B) on the universal chart?

___ 2. Voltage of capacitor during charge

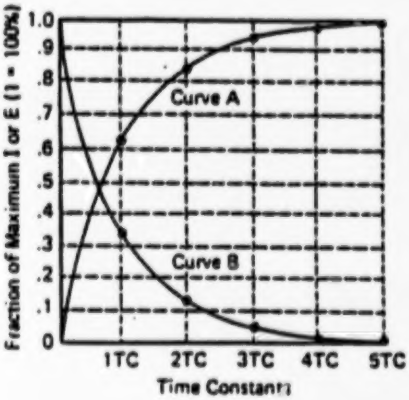
___ 3. Voltage of capacitor during discharge

___ 4. Current during charge

___ 5. Current during discharge

___ 6. Voltage of resistor during charge

___ 7. Voltage of resistor during discharge



8. Compute the following for an RC circuit during **charge** when $E_A = 200$ volts and $R = 50$ ohms. (Use the universal chart.)
   a. Maximum current ____________________
   b. Current after two time constants ____________________
   c. e_C after three time constants ____________________
   d. e_R after three time constants ____________________

9. Compute the following for an RC circuit during **discharge** using the same values for E_A and R as in #8. (Use the universal chart.)
   a. Current after four time constants ____________________
   b. e_C after two time constants ____________________
   c. e_R after two time constants ____________________

10. Compute one time constant for circuits that have the following values.
    a. R = 1 MΩ, C = 1μF TC = _____
    b. R = 1 KΩ, C = 20000μF TC = _____
    c. R = 1500 ohms, C = 200pF TC = _____
    d. R = 47 KΩ, C = 30μF TC = _____

ANSWERS TO ASSIGNMENT SHEET 2.1

1. $Q = CE$

2. a. 100
   b. 100×10^{-6}
   c. 100×10^{-12}
   d. 5000×10^{-6}

3. a. 2.5μF
   b. 40μF
   c. 23.3pF

ANSWERS TO AS 2.2

1. $T = RC$

2. A

3. B

4. B

5. A

6. B

7. A

8. a. 4A
   b. .54A
   c. 190V
   d. 10V

9. a. 0.08A
   b. 173V
   c. 27V

10. a. 1 second
    b. 20 seconds
    c. 0.3μ seconds
    d. 1.41 seconds

JS 2.1

TEST CAPACITORS WITH AN OHMMETER

Equipment:

Ohmmeter
3 capacitors (large, medium and small {less than 0.1 μF})
1 shorted capacitor
1 open capacitor
1 leaky capacitor

WARNING: Always discharge capacitor before and after use.

	Evaluation			
Procedure:	3	2	1	N
1. Place the ohmmeter leads across the large (good) capacitor. Note the swing of the needle across the scale to zero and its return to infinity as the capacitor is charged by the ohmmeter battery.	___	___	___	___
2. Repeat the above step with the medium and small (good) capacitors. Note the smaller deflection of the needle during charge.	___	___	___	___
3. Place the ohmmeter leads across the open capacitor. Note the lack of any deflection of the ohmmeter needle, indicating no current path.	___	___	___	___
4. Place the ohmmeter leads across the shorted capacitor. Note that the needle indicates zero ohms resistance (no return toward infinity and thus no charging of the capacitor plates).	___	___	___	___
5. Place the ohmmeter leads across the leaky capacitor. Note the return of the needle to some specific resistance indication rather than a return to infinity.	___	___	___	___
6. Place the ohmmeter leads across the medium-sized (good) capacitor and permit the indication to return to infinity.	___	___	___	___
7. Reverse the ohmmeter leads and observe the difference in initial ohmmeter needle indication.	___	___	___	___
Average of above evaluations*	___	___	___	___

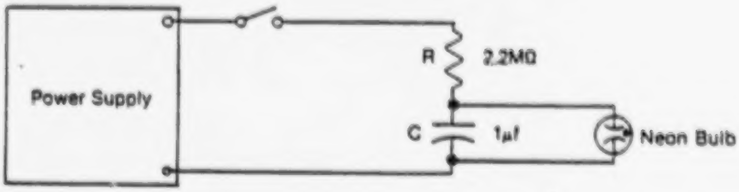
*This average is the student's final evaluation for competency B13: Identify and test capacitors.

CONSTRUCT A NEON LAMP FLASH CIRCUIT

Equipment:

DC power supply, 0-100V
Two 2.2MΩ resistors
Two 1μF capacitors (at least 100V)
Neon bulb

Procedure:	Evaluation 3	2	1	N
1. Connect the circuit as shown below.	___	___	___	___



2. Adjust the power supply to 100 volts. Close the switch and observe the neon bulb.	___	___	___	___
3. Open the circuit and add a 2.2MΩ resistor in series to make a total of 4.4MΩ resistance. Close the switch and observe the neon bulb.	___	___	___	___
4. Open the switch and remove one of the 2.2MΩ resistors.	___	___	___	___
5. Add a 1μF capacitor in parallel with C in the circuit making 2μF of capacitance. Close the switch and observe the neon bulb.	___	___	___	___
6. Draw a sketch of the neon bulb lighting and going out using time as the horizontal axis and voltage as the vertical axis.	___	___	___	___

NOTE: Assume 70 volts will cause the neon bulb to light and it will remain lit until the voltage drops to 40 volts.

7. What are the effects of increasing R and C?	___	___	___	___
8. Return equipment and materials to proper storage area.	___	___	___	___
Average of above evaluation*	___	___	___	___

*This average is the student's partial evaluation for competency B18: Calculate RC time constant circuits.

DETERMINE TIME CONSTANTS OF RC CIRCUITS

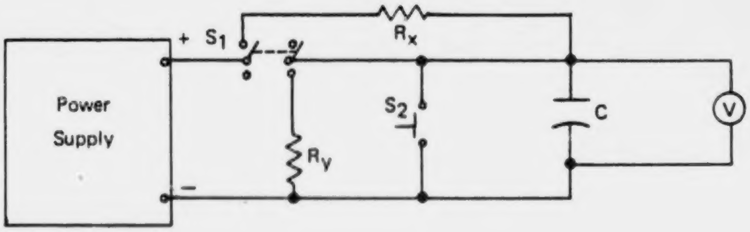
Equipment:

DC power supply, 0-20V
Voltmeter
R_1 - resistor, 100KΩ, 1 watt
R_2 - resistor, 470KΩ, 1 watt
R_3 - resistor, 1MΩ, 1 watt
R_4 - resistor, 2.2MΩ, 1 watt
C_1 and C_2 - Electrolytic capacitor, 10μF, over 20 VDC
S_1 switch, double pole/double throw
S_2 switch, normally open push-button
Stopwatch (or watch with second hand)

Procedure:

Evaluation
3 2 1 N

1. Connect the DC power supply, electronic voltmeter, switches, resistors R_1 and R_2, and capacitor C_1 as shown below; let R_1 and R_2 be R_Y and R_X, and C_1 be C. — — — —



2. Calculate the time constant for the charging circuit above and enter in the table that follows. — — — —

   NOTE: Switch S_1 will be in the up position.

	R-C values Rx	Ry	C	Charge Calculated 1-TC	Charge Calculated 5-TC	Charge Measured Tot. time	Discharge Calculated 1-TC	Discharge Calculated 5-TC	Discharge Measured Tot. time
a.	R_1	R_2	C_1						
b.	R_3	R_4	C_1						
c.	R_4	R_2	C_1 C_2 series						
d.	R_3	R_1	C_1 C_2 parallel						

3. Calculate the total time (five time constants) for the capacitor to be fully charged and enter in the table. — — — —

4. Calculate the time constant for the discharge circuit (S_1 will be in the down position); enter in the table. — — — —

5. Calculate the total time (five time constants) for the capacitor to be fully discharged; enter in table. ___ ___ ___ ___

6. Turn the power supply on and with S_1 in the up position, adjust for 15 volts as indicated by the voltmeter when the capacitor is fully charged. ___ ___ ___ ___

7. Flip S_1 to the down position to isolate the charging source. ___ ___ ___ ___

8. Close S_2 to discharge the capacitor, then release it. ___ ___ ___ ___

9. Start the stopwatch at the same time S_1 is placed in the up position to measure the time required for capacitor C_1 to charge to 15 volts. Record in the table. ___ ___ ___ ___

10. Start the stopwatch at the same time S_1 is placed in the down position to measure the time required for capacitor C_1 to completely discharge; enter in the table. ___ ___ ___ ___

11. Rewire the circuit and repeat steps 2 through 10 for RC values 2, 3 and 4, as shown in table. ___ ___ ___ ___

12. Discuss differences observed in calculated and measured values with the instructor. ___ ___ ___ ___

13. Return equipment and materials to proper storage area. ___ ___ ___ ___

Average of above evaluation* ___ ___ ___ ___

*This average is the student's final evaluation for competency B18: Calculate RC time constant circuits.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VII: ELECTROMAGNETICS AND ELECTROSTATICS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Which describes substances which readily respond to magnetic fields?

a. Reluctant
b. Permeable
c. Retentive
d. Ferromagnetic
e. None of the above

____ 2. Which of the following are lines of force extending from the north to south poles?

a. Field
b. Flux
c. Permeable
d. Retention
e. All of the above

____ 3. What does magnetism exert on objects that it attracts?

a. A resistance
b. A mechanical force
c. Heat
d. Reverse polarity
e. None of the above

____ 4. What is produced by current flowing through a conductor?

a. Electrostatic discharge
b. Electrostatic field
c. Magnetic field
d. Electromagnetic discharge
e. Corona field

____ 5. What rule determines the direction of flux lines for a conductor?

a. Thumb
b. First finger
c. Ring finger
d. Right hand
e. Left hand

____ 6. Forming a conductor into a coil ____________ the magnetic field.

a. Reverses
b. Dissipates
c. Strengthens
d. Elongates
e. None of the above

____ 7. Generating voltage electromagnetically requires a magnetic field, a conductor in the magnetic field and __________ .

a. Relative motion between the conductor and the field
b. Motion of the conductor in parallel with the flux lines
c. No movement on the part of the magnetic field
d. No movement on the part of the conductor
e. None of the above

____ 8. In a generator, what is the magnitude of the induced voltage directly proportional to?

a. Orientation to the earth's magnetic field
b. Number of flux lines cut per second by a conductor
c. Physical size of the conductor
d. Temperature of the electromagnet
e. All of the above

____ 9. When a conductor moves parallel to the lines of force, what is the result?

a. No voltage is generated.
b. Maximum voltage is generated.
c. Magnetic permeability increases.
d. Flux density is maximum.
e. None of the above

____ 10. The induced current caused by self-induction __________ .

a. Is counter to the original current
b. Is called CEMF
c. Occurs when the original current is increasing
d. Occurs when the original current is decreasing
e. All of the above

____ 11. Which of the following is the unit for inductance?

a. Farad
b. Coulomb
c. Pico
d. Henry
e. None of the above

____ 12. What is the symbol for inductance?

a. I
b. K
c. L
d. M
e. None of the above

____ 13. Inductance is affected by which of the following?

a. Number of turns in the coil
b. Material around which the coils are wound
c. Length of the coil
d. All of the above
e. None of the above

____ 14. When one conductor causes an induced voltage in another, what is it called?

a. Partial inductance
b. Parallel inductance
c. Serial inductance
d. Mutual inductance
e. None of the above

____ 15. With no mutual inductance, two inductors in parallel will have a total inductance __________ .

a. Calculated like two resistors in parallel
b. Less than either of the individual inductors
c. Found by the product over the sum method
d. Found by the same reciprocal formula used by resistors
e. All of the above

____ 16. The Farad is the unit of __________ .

a. Inductance
b. Mutual conductance
c. Flux density
d. Capacitance
e. None of the above

____ 17. What is the symbol for capacitance?

a. I
b. F
c. C
d. L
e. None of the above

____ 18. What is insulating material between capacitive plates called?

a. The insulator
b. Dielectric
c. Myoelectric
d. Permelectric
e. None of the above

____ 19. Which of the following usually describes electrolytic and tantalum capacitors?

a. Low-value capacitors
b. Not marked with a voltage rating
c. Polarized
d. Not used in modern electronic equipment
e. All of the above

____ 20. Calculating total capacitance for capacitors in series __________ .

a. Is like resistors in parallel
b. Is the same as resistors in series
c. Can only be measured, not calculated
d. Uses the logarithmic formula
e. None of the above

____ 21. Calculating total capacitance for capacitors in parallel _________ .

a. Is the same as resistors in parallel
b. Is like resistors in series
c. Can only be measured, not calculated
d. Uses the logarithmic formula
e. None of the above

____ 22. What does the rating of WVDC designate?

a. Wave (AC) voltages
b. Wave Voltage Dielectric Capacitance
c. Working Voltage Direct Current
d. Minimum voltage for the capacitor to use
e. None of the above

____ 23. Which of the following describes the three-digit IEC code for capacitors?

a. Similar to the resistor color code
b. Produces a value of capacitance in pico-farads
c. Uses a multiplier digit
d. All of the above
e. None of the above

____ 24. What does the letter K in the IEC capacitor code mean?

a. "Times 1000", as in kilo
b. Tolerance marking for ±10%
c. Temperature coefficient
d. The capacitor is polarized
e. None of the above

____ 25. The RC time constant is _________ .

a. The time required to reach full charge
b. Found by multiplying the resistance times the capacitance
c. The index of dielectric multiplied by the refraction index
d. Increased when the applied voltage is increased
e. All of the above

ANSWERS TO UNIT TEST

1.	d	(B4)
2.	b	(B4)
3.	b	(B4)
4.	c	(B3)
5.	e	(B3)
6.	c	(B3)
7.	a	(B3)
8.	b	(B3)
9.	a	(B3)
10.	e	(B3)
11.	d	(B10)
12.	c	(B10)
13.	d	(B10)
14.	d	(B10)
15.	e	(B10)
16.	d	(B9)
17.	c	(B9)
18.	b	(B9)
19.	c	(B9)
20.	a	(B9)
21.	b	(B9)
22.	c	(B9)
23.	d	(B9)
24.	b	(B9)
25.	b	(B9)

MODULE: FUNDAMENTALS OF ELECTRONICS
UNIT VIII: AC SIGNALS AND MEASUREMENTS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to explain characteristics of alternating current, use the various methods of expressing AC values, use oscilloscopes and multimeters to measure AC signals. This knowledge will be evidenced by achieving the specified score on assignment sheets, job sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Identify terms and definitions.

1.2 Convert between peak, peak-to-peak, rms (effective) and average values of AC signals.

1.3 Calculate wavelength, time period and frequency.

1.4 Calculate quantities in AC circuits.

1.5 Demonstrate the ability to construct a sine-wave cycle. (partial B11, JS 1.1)

2.1 Identify terms and definitions.

2.2 Measure AC voltages using a multimeter. (competency B11, JS 2.1)

2.3 Describe the use of the significant parts of an oscilloscope.

2.4 Measure voltage, time period and phase shift with an oscilloscope.

2.5 Use an oscilloscope and signal generator. (competency H1 and H3, JS 2.2)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VIII: AC SIGNALS AND MEASUREMENTS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: ALTERNATING CURRENT CHARACTERISTICS
    - a. Information outline
    - b. Handout
        - HO 1.1: Sine-wave relationships
    - c. Assignment sheet
        - AS 1.1: Compute AC values
    - d. Answers to assignment sheet
    - e. Job sheet
        - JS 1.1: Construct a sine-wave cycle
2. Lesson 2: AC MEASUREMENTS
    - a. Information outline
    - b. Transparency masters
        - TM 2.1: Simplified CRT block diagram oscilloscope
        - TM 2.2: Pulse width, rise and fall times, and amplitude of rectangular waveforms
    - c. Handouts
        - HO 2.1: CRT components and signal trace
        - HO 2.2: Phase relationship patterns
    - d. Assignment sheets
        - AS 2.1: Calculate oscilloscope display values
        - AS 2.2: Determine phase relationships of AC signals
    - e. Answers to assignment sheets
    - f. Job sheets
        - JS 2.1: Measure AC voltages using a multimeter

JS 2.2: Use an oscilloscope and signal generator

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.
2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.
3. Graf, Rudolf F. Modern Dictionary of Electronics. 6th ed. Indianapolis, IN: Howard W. Sams & Co., Inc., 1984.
4. Schuler, Charles A. Electronics: Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.
5. Schuler, Charles A.; Richard J. Fowler. Basic Electricity and Electronics. St. Louis: McGraw-Hill, 1988.

B. Curriculum guides

1. Hartman, Lonnie. Basic Electronics. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.
2. Robertson, L. Paul. Basic Electronics I. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1980.
3. Vorderstrasse, Ron. General Electronics Technician. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. An oscilloscope manufacturer manual, such as one Tektronics Corporation publishes, contains supplemental information on oscilloscope use. The Tektronic booklet uses Tek scopes as examples but is generic in its approach to oscilloscopes and their uses.
2. Oscilloscope Concepts, Part I (E-87-300). Sedalia, MO: State Fair Community College, 1987. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)
3. Oscilloscope Concepts, Part II (E-87-301). Sedalia, MO: State Fair Community College, 1987. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VIII: AC SIGNALS AND MEASUREMENTS

LESSON 1: ALTERNATING CURRENT CHARACTERISTICS

I. Terms and definitions

   A. Alternation--moving from zero to a maximum (or minimum) and back to zero

      NOTE: One complete cycle of AC has two alternations.

   B. Amplitude--the magnitude of voltage or current at a specific time

   C. Cycle--the series of values of a periodic quantity that occur during one period

      NOTE: One cycle is one complete set of positive and negative values of an alternating current.

   D. Frequency--number of cycles completed in one second

   E. Period--time required to complete one cycle

   F. Hertz--the measure of frequency equal to the number of cycles per second

   G. Electrical degree--1/360th of a cycle

   H. Radian--angular part of a circle or cycle which includes an arc equal to the radius

      NOTE: 360 degrees equals 2π radians. Thus, 1 radian equals 57.3 degrees.

   I. Peak amplitude--maximum value of an alternation

   J. Sine-wave average value--0.637 times the peak value

      NOTE: The average value of a complete sine-wave cycle is zero.

   K. Sine-wave effective value--0.707 times the peak value

      NOTE: This is the value of AC equal to its DC equivalent value.

   L. Sine-wave rms (root-mean-square) value--equals the effective value

   M. Peak-to-peak value--twice the peak or maximum value of an alternation

   N. Wavelength--distance a wave travels in one cycle

II. AC signals

   A. Sine-wave relationships (HO 1.1)

      1. Degrees and radians (conversions)

         a. 2π radians equals 360 degrees.

         b. π radians equals 180 degrees.

c. $\pi + 3$ radians equals $180 + 3$ degrees or 60 degrees. Thus, $\pi + n$ radians equals $180 + n$ degrees.

2. Cycles and radians--One cycle equals 2π radians.

3. Alternation and radians--One alternation equals π radians.

4. Alternation and degrees--One alternation equals 180 degrees.

5. Alternation peak value--equals the maximum value during a positive alternation and the most minimum value during a negative alternation

6. Effective value and peak value--The effective value is obtained by multiplying the peak value by 0.707.

7. Peak-to-peak value and peak value--The peak-to-peak value equals two times the peak value.

B. Sine-wave value conversions

From	To effective	Ave.	Peak	Peak-to-peak
Effective (rms)	1.0	0.900	1.414	2.828
Average	1.110	1.0	1.571	3.142
Peak	0.707	0.637	1.0	2.000
Peak-to-peak	0.354	0.318	0.500	1.0

III. AC signal, time period and frequency

A. Abbreviations of terms relating to alternating current waves

1. E_{max} = maximum voltage

2. I_{max} = maximum current

3. e = instantaneous value of voltage

4. I = instantaneous value of current

5. E = rms or effective value of voltage

6. I = rms or effective value of current

7. T or t = time (used with period)

8. l = wavelength

9. f = frequency

10. Hz = hertz

B. Formulas to compute instantaneous voltage and current values

1. $e = E_{max} \sin \theta$ (θ is the angular displacement)

2. $i = I_{max} \sin \theta$

C. Commonly used values and sine functions

1. Sin 0° = 0
2. Sin 30° = 0.5
3. Sin 45° = 0.707
4. Sin 60° = 0.866
5. Sin 90° = 1
6. Sin 180° = 0
7. Sin 270° = -1
8. Sin 360° = 0

   NOTE: Sin 360° = Sin 0°

D. Frequency groupings

1. Audio frequencies
   - a. Corresponds to normally audible sound waves
   - b. Ranges roughly from 15 Hz to 20,000 Hz
   - c. Electrically produced
2. Sonic frequencies
   - a. Corresponds to normally audible sound waves
   - b. Range: 15-20,000 Hz
   - c. Mechanically produced
3. Radio frequencies
   - a. Above the audio range
   - b. Ranges: 10 KHz to 100,000 MHz
   - c. Electrically produced
4. Ultrasonic frequencies
   - a. Above the audio or sonic range
   - b. Mechanically produced

E. Frequency, period and wavelength

1. Relationships given by formula $T = 1 \div f$ (or $f = 1 \div T$) where T is time (in seconds of a period) and f is frequency (in hertz)

2. Velocity of transmission (v)

   a. Electrical waves travel faster than sound waves.

      NOTE: Electrical waves travel at almost the speed of light--180,000 miles per hour or 300,000 kilometers per second.

   b. Sound waves travel much slower than electrical waves.

      NOTE: Sound waves travel at approximately 760 miles per hour or 332 meters per second in air.

3. Wavelength (λ) equals the velocity divided by the frequency in hertz ($v \div f$). Thus, wavelength varies directly with velocity and wavelength varies inversely with frequency.

IV. Quantities in AC resistive circuits

A. Ohm's law can be used to calculate voltage, current and resistance in resistive AC circuits just as in DC circuits.

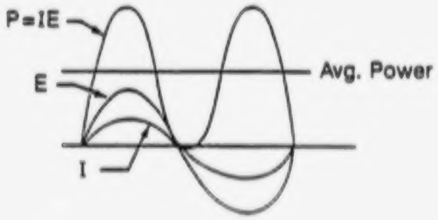
   1. The rules for calculating resistance in series and parallel AC circuits are the same as those used for DC circuits.

   2. The effective value of AC voltage and current is used when performing calculations in AC circuits that contain only resistance.

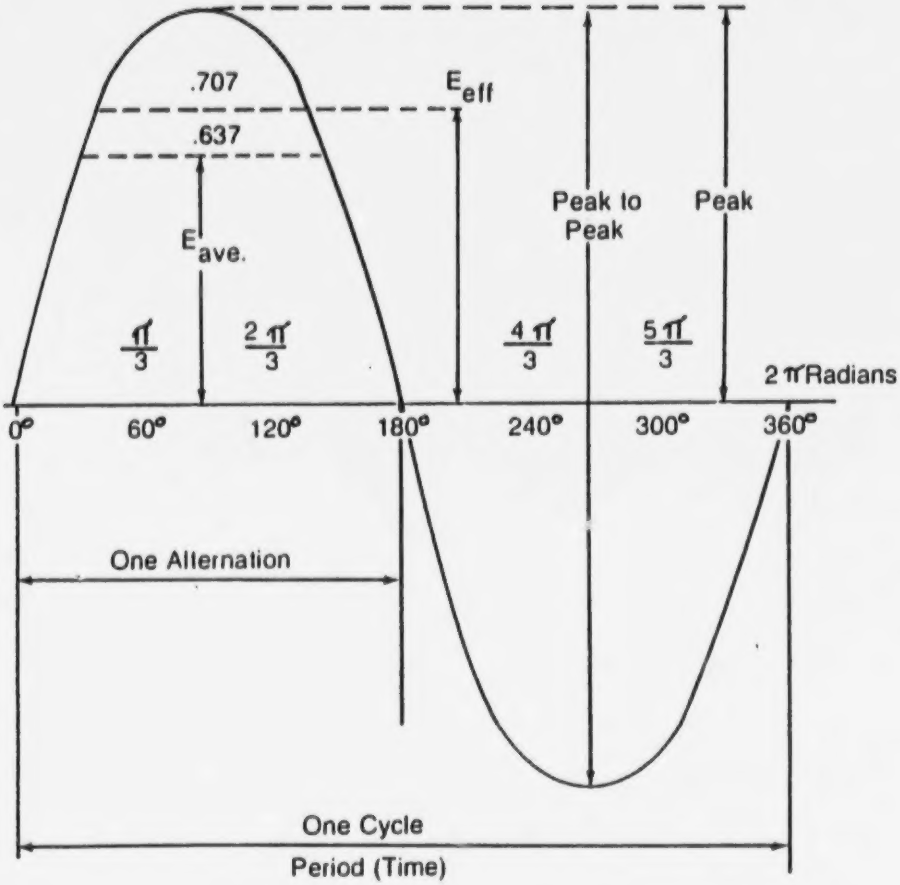
B. Power is consumed in a resistive AC circuit in the form of heat dissipated by the resistor.

   1. The rules used for power in DC circuits can be applied to AC circuits.

   2. Effective values of voltage and current are used to determine average power.



SINE-WAVE RELATIONSHIPS


.707
Eeff
.637
Eave.
Peak to Peak
Peak
π/3
2π/3
4π/3
5π/3
2π Radians
0°
60°
120°
180°
240°
300°
360°
One Alternation
One Cycle
Period (Time)

AS 1.1

COMPUTE AC VALUES

Sine-wave conversions

1. An oscilloscope shows that the peak voltage value of an AC wave is 155.6 volts. What is the voltage that would be read on the AC scale of a multimeter (i.e., rms voltage value)? __________

2. If the voltmeter reads 25 volts rms (effective value), what is the peak voltage shown on an oscilloscope (peak value)? __________

3. In problem 2, what would the peak-to-peak voltage be? ___________

4. If the peak value of a sine wave is 100, the average value of one alternation is ________________.

Period and wavelength

Formulas:

$$T = \frac{1}{f} \qquad f = \frac{1}{t} \qquad \lambda = \frac{v}{f} = \frac{v}{1 + t} \text{ or } vt \qquad f = \frac{v}{d}$$

NOTE: Radio waves have a velocity of 3×10^{10} cm + s or 186,000 miles + s.

5. How much time is required for a 60 cycle per second (60 Hz) voltage to complete one cycle? _____________ seconds

6. If one cycle requires 1/400th of a second, the frequency is _________ Hz.

7. If frequency is increased, the time required for one cycle will (increase / decrease).

8. A radio station transmits on a frequency of 780 kilohertz. The wavelength is ______________.

9. Some amateur radio operators have transmitters operating in the 10-meter band. Approximately what frequency are they using? __________________

10. A radio amateur operating on a wavelength of 80 meters is transmitting at a (higher / lower) frequency than one operating on 20 meters.

11. A 100 MHz wave has a wavelength of _____________ cm.

12. If frequency is increased, the wavelength is (increased or decreased).

13. 3×10^{10} cm + s = ___________ m + s.

14. 186,000 miles per second equals ___________ miles per hour.

ANSWERS TO AS 1.1

1. 110 volts
2. 35.35 volts
3. 70.7 volts
4. 63.7
5. 1/60 second
6. 400 Hz
7. decrease
8. 3.846×10^4 cm (or equivalent)
9. 30 MHz
10. lower
11. 300
12. decreased
13. 3×10^8
14. 6.696×10^8 (or 669,600,000)

CONSTRUCT A SINE-WAVE CYCLE

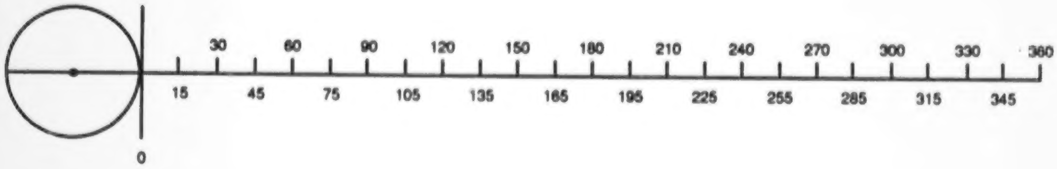
Equipment:

Graph paper
Compass
Protractor
Ruler
Calculator (or square-root tables)

Procedure: Evaluation 3 2 1 N

1. Draw a circle with a radius of 10 graph-paper units on the extreme left side of your graph paper. Draw the circle's diameter and extend it across the paper. ___ ___ ___ ___

2. Draw the tangent to the circle on the right end of the diameter line. Mark off 15° increments from 0 to 360 degrees, letting the diameter line be the 0° mark. ___ ___ ___ ___



3. Use a protractor to mark off the upper half of the circle in 15° increments. ___ ___ ___ ___

4. Measure the vertical distance from the base line to the 15° line intersection with a compass and transfer this distance to the 15° mark to the right; repeat for each 15° mark. ___ ___ ___ ___

   NOTE: Carefully mark the intersection of each 15° line and the circle.

5. Make a table of the degrees versus the vertical distances, letting the maximum vertical distance be one. (All other distances will be less than one, and one is at the 90° position.) ___ ___ ___ ___

6. Make a smooth curve between the points plotted to the right of the circle. ___ ___ ___ ___

   NOTE: This will be the graph of a sine-wave cycle.

7. Compute the average vertical height of one alternation by adding the heights in one alternation and dividing by the number of heights. ___ ___ ___ ___

   ____

8. Using the table, square each height. Then compute the average of these squared heights. ___ ___ ___ ___

9. Using a calculator or use a square-root table, calculate the square root of the average squared height obtained in the previous step; this rms value is __________ . ___ ___ ___ ___

10. Discuss with the instructor how your computations compare with an AC voltage's maximum (peak) value of one volt. _ _ _ _

Average of above evaluation* _ _ _ _

*This average is the student's partial evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VIII: AC SIGNALS AND MEASUREMENTS

LESSON 2: AC MEASUREMENTS

I. Terms and definitions

NOTE: Most controls on an oscilloscope are labeled with abbreviations. The names of some controls vary slightly. A technician should consult the operation manual for the particular oscilloscope in use to become familiar with control names, abbreviations and functions.

A. Power switch--turns oscilloscope on and off

B. Scale illumination--illuminates the graticule on the CRT display

C. Focus--adjusts image clarity and sharpness of the waveform presentation on the CRT display

D. Calibration--provides a calibration signal to adjust the oscilloscope for accurate measurements

E. Intensity--adjusts image brightness of the displayed waveform

F. Phosphor--layer of luminous material on the inner side of a CRT. As bombarded by electrons, it alternately glows and fades.

G. Sweep mode--selects which channel will be displayed on the CRT display

H. Horizontal position--moves image to the right or left on the CRT display

I. Sweep time/cm--selects horizontal sweep rate which compresses or expands the displayed waveform

J. External horizontal input--provides for an external input to allow control of the horizontal sweep by an external signal

K. Trigger source--selects the signal to initiate or trigger the sweep

L. Trigger level--selects voltage level of the triggering waveform that initiates the sweep

M. External trigger--provides for the input of an external voltage to be used as the trigger to initiate the sweep

N. Vertical position--provides for positioning of the image up or down on the CRT display

O. Coupling--selects between DC or AC inputs

P. Channel A and Channel B input--provides for the connection of input voltages to each of two channels

II. VOM measurements of AC signals

A. Calibrated for sine waves only, unless otherwise stated

B. Calibrated to read AC rms only, unless otherwise stated

C. VOM scale for AC may not be the same scale as for DC.

III. Oscilloscope construction

A. An oscilloscope display consists of three primary parts.

1. The cathode ray tube (CRT) is the heart of the oscilloscope and provides the visual display of electronic signals. (HO 2.1)

2. The electron gun provides a fine beam of high-velocity electrons that bombard the phosphor screen of the CRT. This causes the phosphor to glow, which creates the visual presentation on the CRT.

3. Electrostatic deflection plates control both the horizontal and vertical movement of the electron beam.

B. Electronic circuits within the oscilloscope allow operator and automatic control of the electron beam to provide a useful presentation on the CRT screen. (TM 2.1)

C. Deflection plates are driven by amplifiers, which generally increase the input to cause a specific deflection of the electron beam.

D. The horizontal amplifier has two inputs.

1. An external input is displayed on the horizontal axis

2. The other input, from the sweep generator, produces a horizontal trace across the screen.

IV. Measurements that can be taken with an oscilloscope

A. Oscilloscopes measure voltage and time.

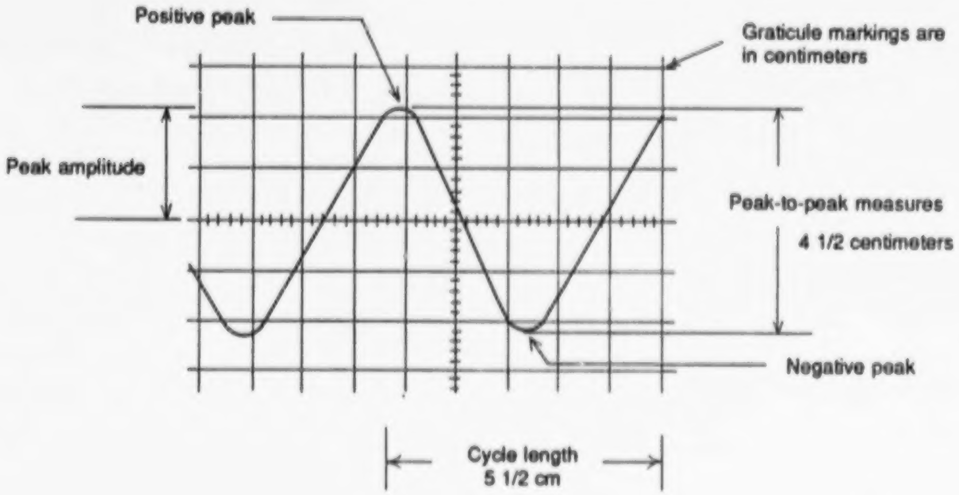
B. All measurements are made with the graticule on the oscilloscope screen.

C. The shape, phase and frequency of the voltage waveform can be viewed while measurements are being made.

D. An oscilloscope can be used to measure DC voltage. This is done by counting the number of divisions on the graticule that the trace moves up or down when the voltage is applied to the input, then multiplying the number of divisions by the volts/cm setting.

E. The peak and peak-to-peak voltages of an AC waveform can be measured by counting the number of vertical divisions on the graticule that the waveform displaces.

Example: Measure the sine-wave peak-to-peak distance with the graticule on the oscilloscope.


Positive peak
Graticule markings are in centimeters
Peak amplitude
Peak-to-peak measures
4 1/2 centimeters
Negative peak
Cycle length
5 1/2 cm

1. Check the volts/cm selector position. To get peak-to-peak voltage, multiply that value by peak-to-peak graticule measurement.
2. 4 1/2 cm x 2 volts/cm = 9 volts peak-to-peak
3. Peak voltage = 1/2 of peak-to-peak, or 4.5 volts
4. To convert to rms value, multiply peak by 0.707 (3.18 volts rms).

F. The frequency of a sine wave can be determined by counting the number of divisions that one cycle displaces and multiplying that number by the sweep time/cm setting on the oscilloscope.

Example:

1. Measure the length of one cycle with the oscilloscope graticule.
2. Multiply that value by the sweep time/cm setting on the oscilloscope to get the time of one cycle.

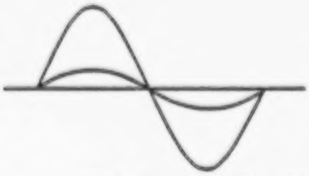
   5 1/2 cm x 5 ms/cm = 0.02755
3. Use the formula f = 1 + t to find frequency.

$$f = \frac{1}{t} = \frac{1}{0.0275} = 36.36 \text{ Hz}$$

G. Pulse width, rise and fall time, and amplitude of rectangular waveforms can be measured with the oscilloscope. (TM 2.2)

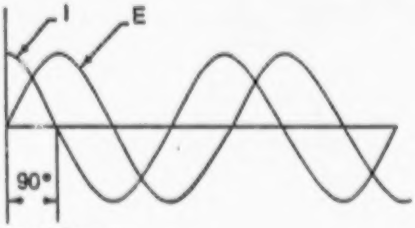
H. Phase relationships

1. When two waveforms coincide so that the maximum instantaneous values both occur at the same time, they are in phase.



In-Phase Relationship

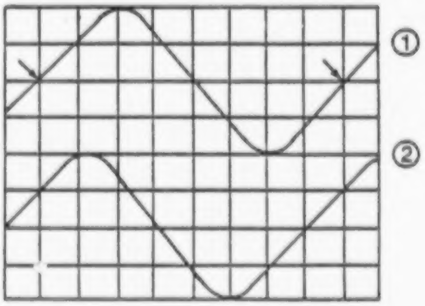
2. When two waveforms do not occur at the same time, they are out of phase.



90° Out-of-Phase

3. The amount of phase displacement is usually measured in degrees.

4. Phase relationships can be determined by comparing waveforms while simultaneously displaying them on a dual-trace oscilloscope. (HO 2.2)

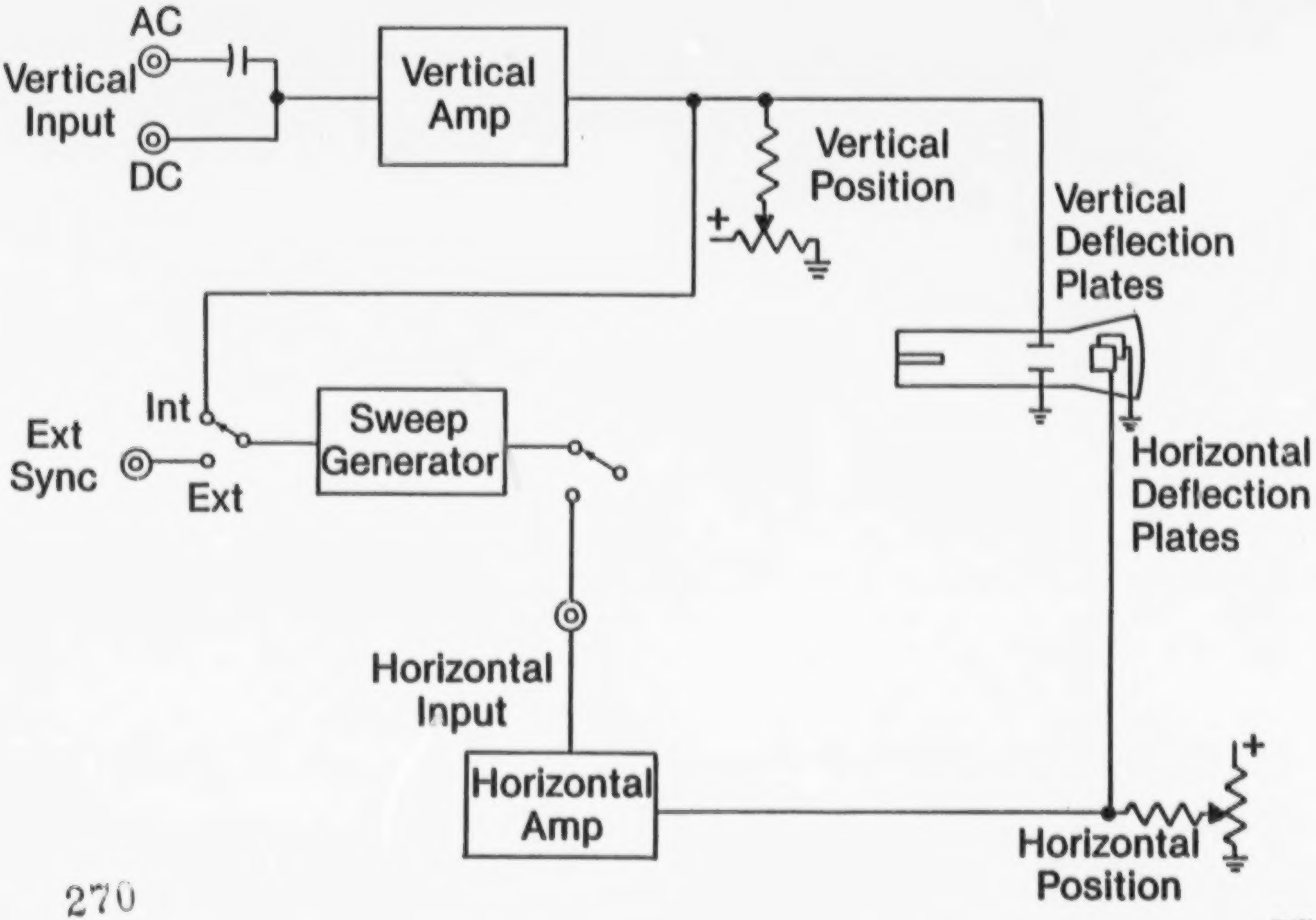


One cycle = 8 cm
1 cm = 45°

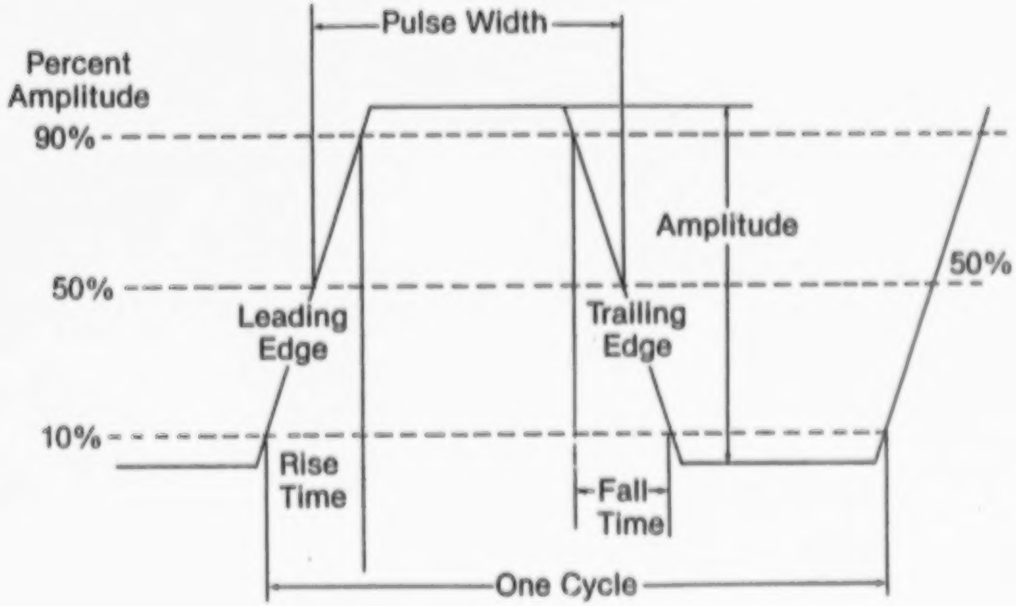
Phase difference = #cm × 45°
1 cm × 45° = 45°

5. Phase relationships can also be determined from Lissajous patterns displayed on an oscilloscope.

SIMPLIFIED CRT BLOCK-DIAGRAM OSCILLOSCOPE


AC
Vertical Input
DC
Vertical Amp
Vertical Position
+
Vertical Deflection Plates
Int
Ext Sync
Ext
Sweep Generator
Horizontal Deflection Plates
Horizontal Input
Horizontal Amp
+
Horizontal Position

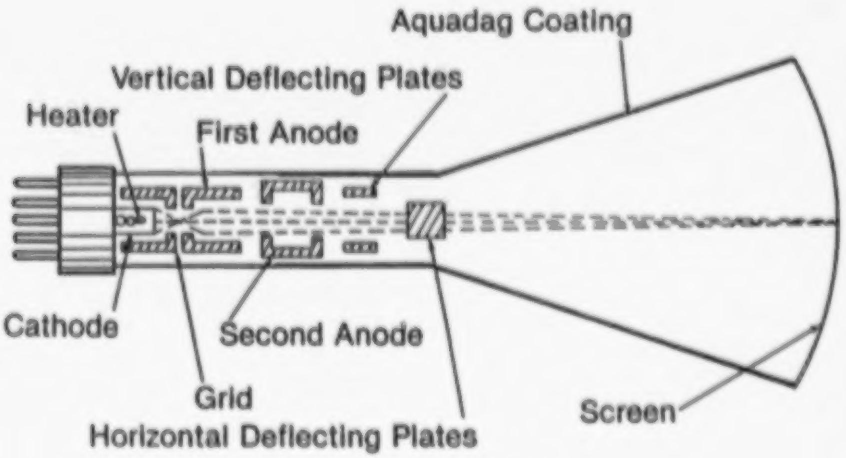
PULSE WIDTH, RISE AND FALL TIMES AND AMPLITUDE OF RECTANGULAR WAVEFORMS


Pulse Width
Percent Amplitude
90%
50%
10%
Amplitude
50%
Leading Edge
Trailing Edge
Rise Time
Fall Time
One Cycle

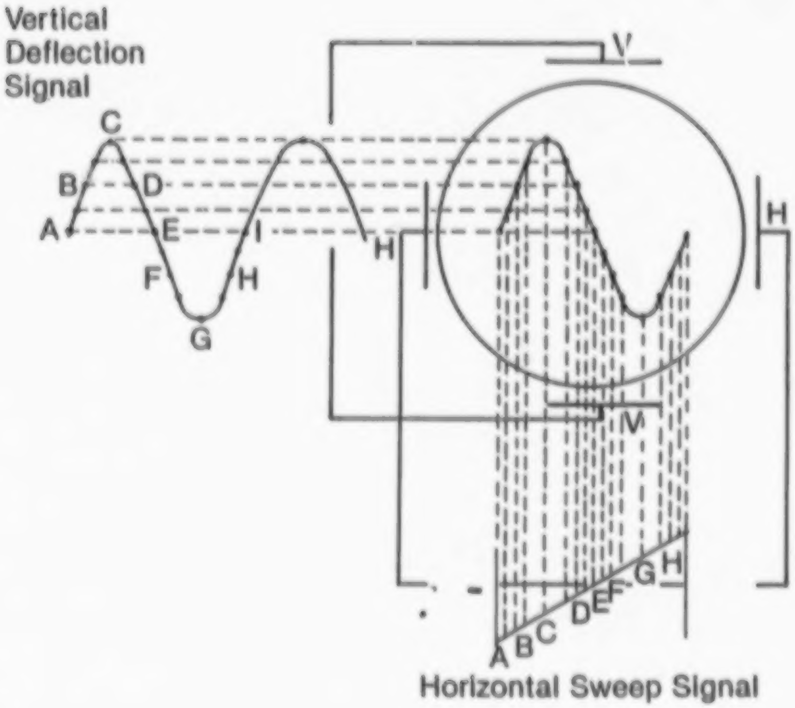
272

CRT COMPONENTS AND SIGNAL TRACE

CRT
(With Electrostatic
Deflection/Focusing)

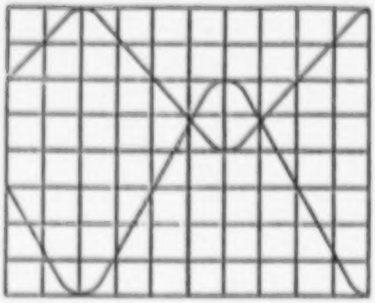

Aquadag Coating
Vertical Deflecting Plates
Heater
First Anode
Cathode
Second Anode
Grid
Horizontal Deflecting Plates
Screen

CRT Signal Trace

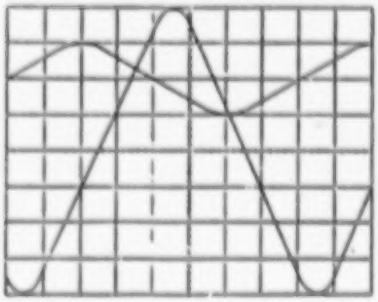

Vertical
Deflection
Signal
A
B
C
D
E
F
G
H
I
H
V
H
V
A B C D E F G H
Horizontal Sweep Signal

PHASE RELATIONSHIP PATTERNS

AC Signals

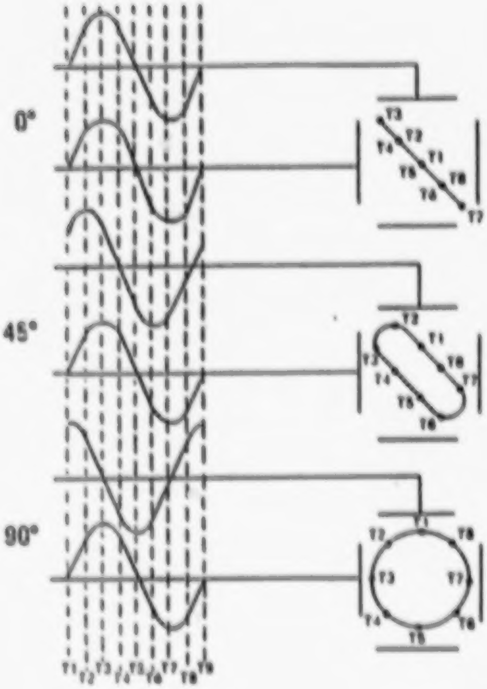


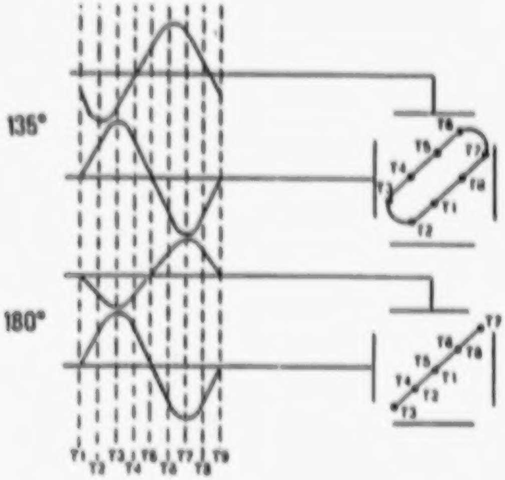
1 Cycle = 8 cm
1 cm = 45°
4 cm between Peaks
4 cm x 45° = 180°
or 180° Out of Phase



2.6 cm x 45° = 117°
or 117° Out of Phase

Lissajous


0°
45°
90°
T1 T2 T3 T4 T5 T6 T7 T8 T9

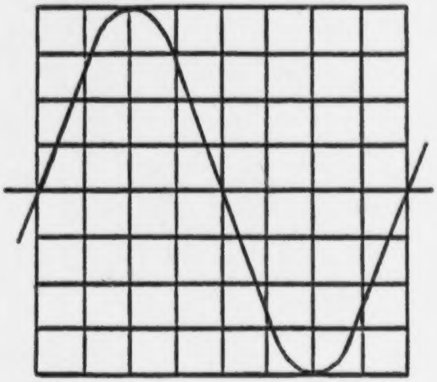

135°
180°
T1 T2 T3 T4 T5 T6 T7 T8 T9

CALCULATE OSCILLOSCOPE DISPLAY VALUES

Calculate the effective or root-mean-square (rms) voltage for each waveform in the problems below.

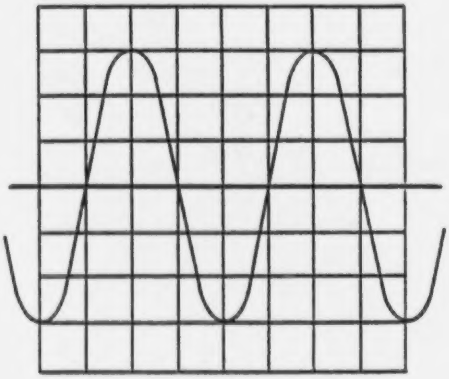
1. Volts/cm set at 2

   Probe is 10 x = ________ V_{RMS}



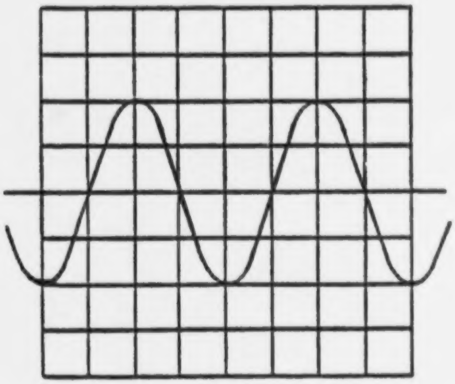
3. Volts/cm set at 0.5

   Probe is 10 x = ________ V_{RMS}



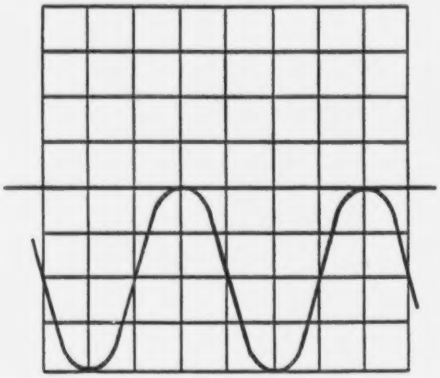
2. Volts/cm set at 0.05

   Probe is 1 x = ________ V_{RMS}



4. Volts/cm set at 20

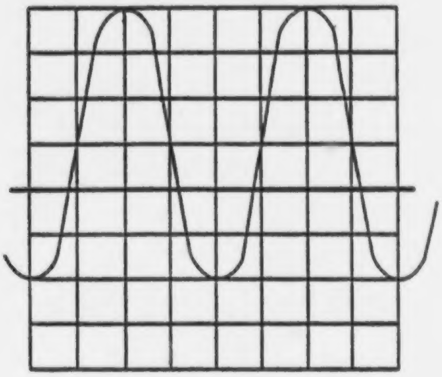
   Probe is 1 x = ________ V_{RMS}



Calculate the time and frequency for each waveform given below. Use metric prefixes in answers as appropriate.

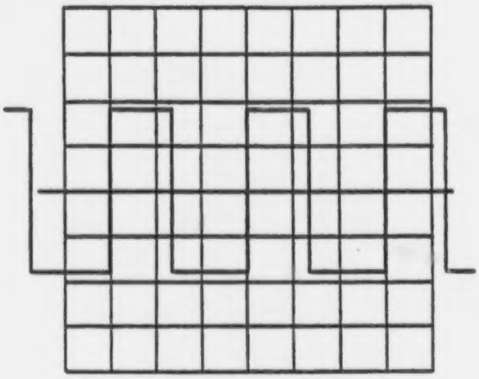
5. Time/cm set at 2μs/cm

_______ s;_________ Hz



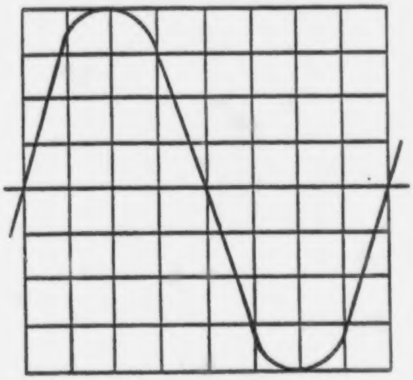
7. Time/cm set at 1s/cm

_______ s; _________ Hz



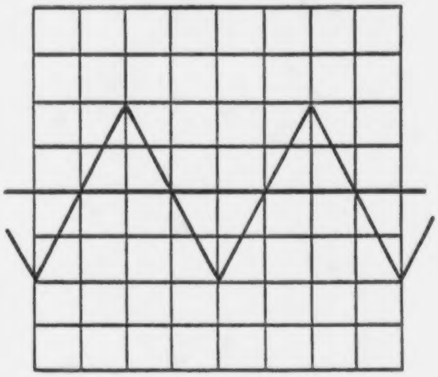
6. Time/cm set at 1 ms/cm

_______ s; _______



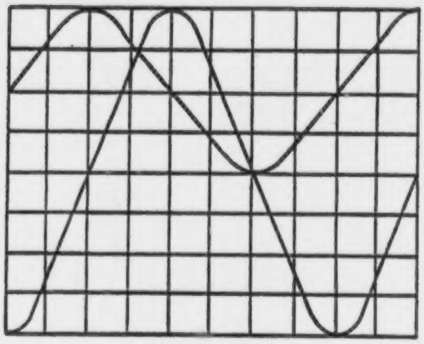
8. Time/cm set at 0.2 ms/cm

_______ s; _________ Hz

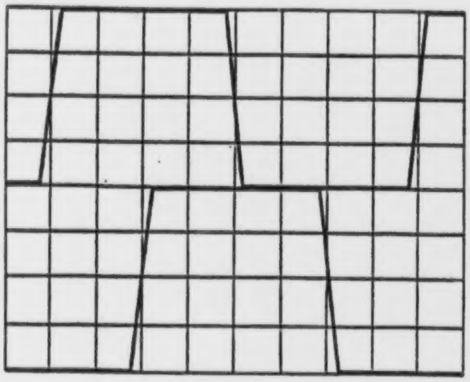


DETERMINE PHASE RELATIONSHIPS OF AC SIGNALS

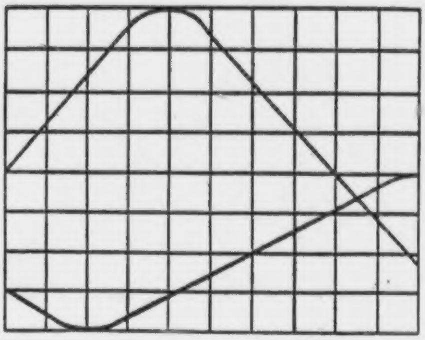
Calculate the phase relationships of the oscilloscope displays below.



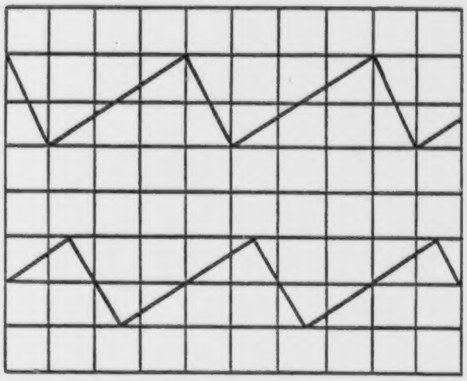
1. ________° out of phase



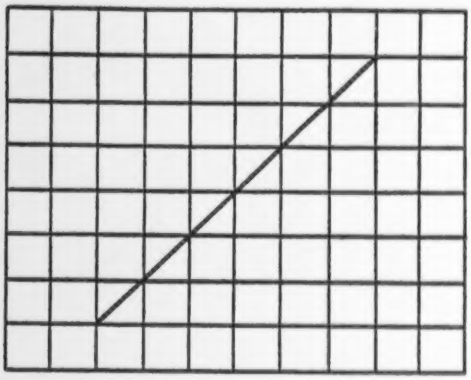
3. ________° out of phase



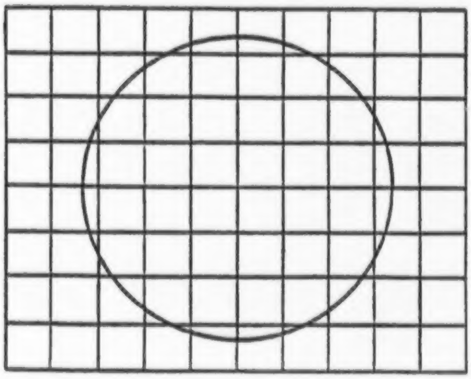
2. ________° out of phase



4. ________° out of phase



5. ________° out of phase



6. ________° out of phase

ANSWERS TO AS 2.1

1. 56.56
2. 0.0707
3. 10.605
4. 28.28
5. 8μs; 0.125 MHz
6. 8ms; 0.125 KHz
7. 3s; 0.33 Hz
8. 0.8μs; 1.25 KHz

ANSWERS TO AS 2.2

1. 90
2. 135
3. 90
4. 135
5. 180
6. 90

JS 2.1

MEASURE AC VOLTAGES USING A MULTIMETER

Equipment:

Multimeter with test leads
Alternate current power sources (24V transformer, rheostat, etc.)

Procedure:	Evaluation 3	2	1	N
1. Set multimeter control to measure AC volts. Measure "line voltage" of power receptacle at the work bench. See diagram below. Record the readings below.	___	___	___	___

WARNING: 120 volts can cause injury or death. Do not touch the metal parts of the test leads while measuring.

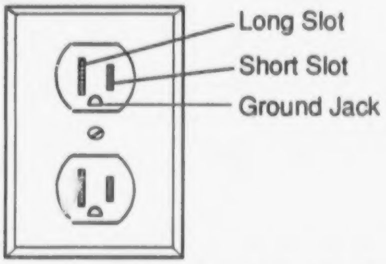
a. Voltage between slotted jacks: ____________________

b. Voltage between longest slotted jack and ground jack:

____

c. Voltage between short-slotted jack and ground jack:

____



NOTE: If voltage is measured in step b, the receptacle is wired incorrectly. Notify your instructor.

	3	2	1	N
2. Attach the equipment given to you by the instructor to specified power source.	___	___	___	___
3. Measure output voltages. Record data below for those devices specified by the instructor. Show results to the instructor.	___	___	___	___

a. Voltage at setting specified by instructor: ______
b. Transformer output voltage: ____________________

c. Rheostat output voltage at setting specified by instructor:

____

d. Other devices or sources of AC voltage

1) Name: ____________________________

2) Voltage: ____________________________

	3	2	1	N
4. Return equipment and materials to their proper storage area.	___	___	___	___

Average of above evaluation* ___ ___ ___ ___

*This average is the student's partial evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

JS 2.2

USE AN OSCILLOSCOPE AND SIGNAL GENERATOR

Equipment:

Oscilloscope
Signal generator
Test leads
Dual-trace oscilloscope (for DC measurement)
DC power supply (DC measurement)
Test leads (DC measurement)
Oscilloscope (for probe calibration)
Oscilloscope probe (probe calibration)

	Evaluation			
Procedure:	3	2	1	N
Adjust controls for stable waveform display				
1. Set up oscilloscope for operation. (Consult the operating manual.)	__	__	__	__
2. Turn on signal generator. Connect signal generator to oscilloscope.	__	__	__	__
3. Adjust the volts/cm so that the peak-to-peak amplitude is visible on the screen.	__	__	__	__
4. Set trigger control to internal position; select channel that has the signal generator as an input.	__	__	__	__
5. Adjust trigger level and slope controls until waveform is stable. Set sweep time/cm so that waveform is only a few cycles in length.	__	__	__	__
6. Readjust all controls to obtain the clearest and most stable trace possible. Ask instructor to check the resulting waveform.	__	__	__	__
7. Turn off oscilloscope and signal generator.				
Measure frequency				
1. Set up the oscilloscope and signal generator.	__	__	__	__
2. Connect signal generator to oscilloscope. Adjust oscilloscope for a stable waveform.	__	__	__	__
3. Determine the time of the sine wave. Record sine-wave time. ______________	__	__	__	__
4. Calculate frequency of sine wave. Record the frequency. ________________ (Check answer with the instructor.)	__	__	__	__
5. Turn off oscilloscope and signal generator.	__	__	__	__
Measure AC voltage				
1. Set up oscilloscope and signal generator for operation.	__	__	__	__
2. Connect signal generator to oscilloscope. Adjust oscilloscope for a stable waveform.	__	__	__	__

3. Measure and record the voltages. (Check answers with the instructor.) ___ ___ ___ ___

_______ peak-to-peak; _________ rms

4. Turn off oscilloscope and signal generator. ___ ___ ___ ___

Measure DC voltage

1. Set up oscilloscope and power supply for operation. ___ ___ ___ ___

2. Connect power supply to oscilloscope. Adjust oscilloscope to measure DC voltage. ___ ___ ___ ___

3. Measure voltage and record your results. ___________ (Check answers with the instructor.) ___ ___ ___ ___

4. Turn off oscilloscope and power supply. ___ ___ ___ ___

Probe calibration

1. Set up oscilloscope for operation. ___ ___ ___ ___

2. Connect oscilloscope probe to oscilloscope input. ___ ___ ___ ___

3. Connect probe to calibration jack on oscilloscope. Adjust oscilloscope for stable square-wave display on cathode-ray tube. ___ ___ ___ ___

4. Check square-wave signal for distortion in signal. Adjust oscilloscope probe for no distortion in displayed signal. ___ ___ ___ ___

NOTE: If the square-wave signal has no distortion, vary adjustment watching for distortion. If distortion cannot be eliminated, notify instructor. Have instructor check your work.

5. Return equipment and materials to their proper storage location. ___ ___ ___ ___

Average of above evaluations* ___ ___ ___ ___

*This average is the student's final evaluation for competencies H1 and H3.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT VIII: AC SIGNALS AND MEASUREMENTS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Alternating current values are ________ .

- a. In effective values unless otherwise indicated
- b. In rms values unless otherwise indicated
- c. In values that conform with Ohm's law
- d. Not peak values unless specifically indicated
- e. All of the above

____ 2. A 120V outlet's highest instantaneous voltage will be ________ .

- a. 120V
- b. Typically slightly less than 120V
- c. Approximately 340V
- d. Approximately 170V
- e. None of the above

____ 3. One alternation is ________ .

- a. One-half an AC cycle
- b. Two AC cycles
- c. Both positive and negative
- d. Neither positive nor negative
- e. None of the above

____ 4. The peak-to-peak value is ________ .

- a. 1.414 times the average value
- b. Twice the peak value
- c. Three times the rms value
- d. All of the above
- e. None of the above

____ 5. To convert the rms value to a peak value, multiply the rms value by ________ .

- a. 1.414
- b. 0.707
- c. 2
- d. 0.637
- e. None of the above

____ 6. A 60Hz wave will have a time period of ________ .

- a. 60 seconds
- b. 30 seconds
- c. 16.7 milliseconds
- d. 8.33 milliseconds
- e. None of the above

____ 7. A wave has a time period of 4msec; its frequency is __________ .

a. 4Hz
b. 40Hz
c. 250Hz
d. 2500Hz
e. None of the above

____ 8. The symbol for frequency is __________ .

a. s
b. z
c. f
d. Hz
e. None of the above

____ 9. The effective value of a 2Vp-p signal is __________ .

a. 2V
b. 1V
c. 0.707V
d. 1.414V
e. None of the above

____ 10. The peak value of a 2Vp-p signal is __________ .

a. 2V
b. 1V
c. 0.707V
d. 1.414V
e. None of the above

____ 11. An oscilloscope displays voltages in __________ values.

a. Peak
b. Peak to peak
c. rms
d. Average
e. None of the above

____ 12. Using the 10x probe means that the __________ .

a. Time displayed is 10 times smaller than actual value
b. Time displayed is 10 times larger than actual value
c. Voltage displayed is 10 times smaller than actual value
d. Voltage displayed is 10 times larger than actual value
e. None of the above

____ 13. Moving the selector from 5V to 1V per division will __________ .

a. Increase the size of the signal displayed
b. Decrease the size of the signal displayed
c. Cause the monitored signal to increase in value
d. Cause the monitored signal to decrease in value
e. None of the above

___ 14. Moving the selector from 1msec to 2msec per division will ______ .

- a. Cause the monitored signal to increase in frequency
- b. Cause the monitored signal to decrease in frequency
- c. Increase the amount of cycles displayed
- d. Decrease the amount of cycles displayed
- e. None of the above

___ 15. A phase shift ________ oscilloscope.

- a. Is best observed on a single-trace
- b. Is more easily observed on a dual-trace
- c. Can be observed only with a digital-storage
- d. Cannot be observed on an
- e. Can damage an

Match the following terms and definitions.

___ 16. Measure of frequency equal to the number of cycles per second

___ 17. Series of values of a periodic quantity that occur during one period

___ 18. Number of cycles completed in one second

___ 19. Angular part of a circle or cycle which includes an arc equal to the radius

___ 20. Magnitude of voltage or current at a specific time

___ 21. 0.707 times the peak value

___ 22. 1/360th of a cycle

___ 23. Selects the channel that will be displayed on the CRT display

___ 24. Moving from zero to a maximum (or minimum) and back to zero

___ 25. Selects horizontal sweep rate which compresses or expands the displayed waveform

___ 26. Selects the signal to initiate or trigger the sweep

___ 27. Selects between DC or AC inputs

- a. Alternation
- b. Amplitude
- c. Coupling
- d. Cycle
- e. Electrical degree
- ab. External trigger
- ac. Frequency
- ad. Hertz
- ae. Period
- bc. Radian
- bd. Sine-wave effective value
- be. Sweep time/cm
- cd. Sweep mode
- ce. Trigger source

ANSWERS TO UNIT TEST

1.	e	(B11)
2.	d	(B11)
3.	a	(B11)
4.	b	(B11)
5.	a	(B11)
6.	c	(B11)
7.	c	(B11)
8.	d	(B11)
9.	c	(B11)
10.	b	(B11)
11.	b	(H1)
12.	d	(H1)
13.	a	(H1)
14.	d	(H1)
15.	b	(H1)
16.	ad	(B11)
17.	d	(B11)
18.	ac	(B11)
19.	bc	(B11)
20.	b	(B11)
21.	bd	(B11)
22.	e	(B11)
23.	cd	(H1)
24.	a	(B11)
25.	be	(H1)
26.	ce	(H1)
27.	c	(H1)

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IX: REACTIVE AND RESONANT CIRCUITS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to explain the operation of filters and the effects of reactive components on circuit performance. This knowledge will be evidenced by achieving the specified score on job sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Define reactance terms and definitions.

1.2 Determine characteristics of inductive AC circuits. (competency B10)

1.3 Determine characteristics of capacitive AC circuits. (competency B11)

1.4 Demonstrate the ability to: (competency B11)

- a. Determine effect of inductance in AC circuits
- b. Determine values of an operating RL circuit
- c. Determine effect of AC and DC on capacitors
- d. Determine effect of capacitive reactance in AC circuits
- e. Determine capacitive reactance and impedance in RC circuits

2.1 Define terms and definitions related to resonant circuits. (competency B19)

2.2 Describe resonance and calculate resonant values. (competency B11)

2.3 Describe the various types of filter circuits. (competency B19)

2.4 Demonstrate the ability to: (competency B20)

- a. Determine resonance in a series RCL circuit
- b. Determine resonance in a parallel RCL circuit

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IX: REACTIVE AND RESONANT CIRCUITS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: REACTANCE
    - a. Information outline
    - b. Transparency master
        - TM 1.1: Current and voltage relationships in an AC circuit
    - c. Assignment sheets
        - AS 1.1: AC inductive circuits
        - AS 1.2: AC capacitive circuits
    - d. Answers to assignment sheets
    - e. Job sheets
        - JS 1.1: Determine effect of inductance in AC circuits
        - JS 1.2: Determine values of an operating RL circuit
        - JS 1.3: Determine effect of AC and DC on capacitors
        - JS 1.4: Determine effect of capacitive reactance in AC circuits
        - JS 1.5: Determine capacitive reactance and impedance in RC circuits
2. Lesson 2: RESONANT CIRCUITS
    - a. Information outline
    - b. Transparency masters
        - TM 2.1: Resonant curves
        - TM 2.2: Tuned parallel circuit curves
    - c. Handouts
        - HO 2.1: Impedance, voltage and resonance relationships in series RCL circuits
        - HO 2.2: Current and resonance relationships in parallel RCL circuit
    - d. Assignment sheets
        - AS 2.1: Series resonant circuits
        - AS 2.2: Parallel resonant circuits

e. Answers to assignment sheets

f. Job sheets

JS 2.1: Determine resonance in a series RCL circuit
JS 2.2: Determine resonance in a parallel RCL circuit

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Douglas-Young, John. Illustrated Encyclopedic Dictionary of Electronics. West Nyack, NY: Parker Publishing Co., Inc., 1981.

2. Fowler, Richard J. Electricity Principles and Applications. 2nd ed. St. Louis: McGraw-Hill, 1984.

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B. Curriculum guides

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MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IX: REACTIVE AND RESONANT CIRCUITS

LESSON 1: REACTANCE

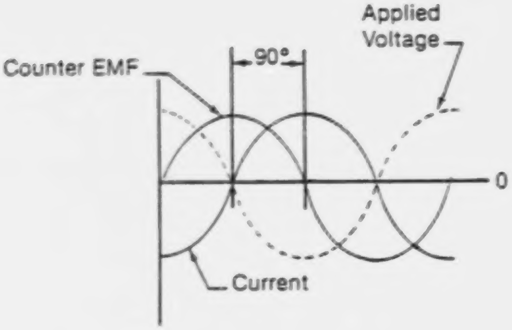
I. Terms and definitions

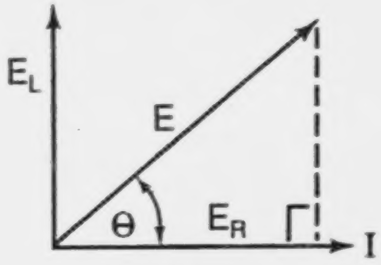
- A. Reactance--opposition to current flow, measured in ohms, that occurs due to the presence of an inductor or capacitor in a circuit. The opposition is actually due to the component's "reaction" to the changing values of AC inputs.

- B. Quality--relative value of a reactive component (usually an inductor, coil or choke) compared to its resistance; a ratio of reactance to resistance called Q

II. Inductive AC circuits

- A. Current and voltage relationships (TM 1.1)
  - 1. When AC voltage is applied to an inductor, the AC current which flows produces a varying magnetic field that induces a voltage into the inductor.
    - a. The induced voltage is 180° out of phase with the applied voltage.
    - b. If the circuit current is a sine wave, the induced voltage will be a sine wave.
    - c. The current's rate of change determines the amplitude of the induced voltage.
  - 2. Counter EMF is 90° out of phase with the circuit current.





Vector Diagram of Series RL Circuit

  - 3. Current flowing in an inductive circuit is directly proportional to the voltage applied and inversely proportional to the inductive reactance. This current can be represented by the formula $I = E + X_L$.

- B. Characteristics of inductive reactance
  - 1. Inductive reactance is the opposition to AC.
  - 2. Inductive reactance is directly proportional to the inductance and frequency of the applied voltage.

a. As frequency increases, the rate of change in current increases and inductive reactance becomes greater.

b. As frequency decreases, the rate of change in current decreases and causes inductive reactance to decrease.

C. Quality of inductors

1. A manufactured inductor is not pure because the wire inside the coil has resistance.

2. Because power can only be dissipated by resistance, the only resistance in a coil is that within the wire used to make the coil.

3. Inductors are compared in quality by a merit figure called Q.

4. The Q of a coil is the ratio of energy stored in the coil in the form of a magnetic field to the energy dissipated in the resistance of the coil.

5. The Q of a coil can also be expressed as a ratio of inductive reactance to the resistance.

$$Q = \frac{X_L}{R}$$

6. Since Q is directly proportional to the inductive reactance, Q increases with frequency.

D. Characteristics of voltage and current in RL circuits

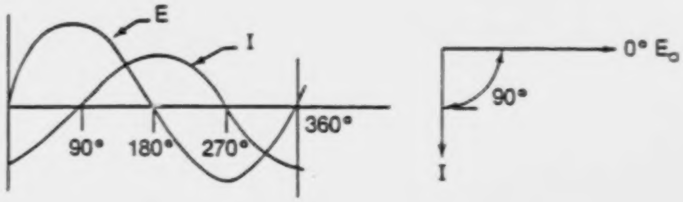
1. AC current flow in an RL circuit causes voltage drops across the resistor and the inductor.

2. The voltage drop across the resistor can be found using Ohm's law ($E_R = IR$).

3. The voltage drop across the inductor can also be found using Ohm's law ($E = IX_L$).

4. Circuit current in an RL circuit lags the applied voltage by 90°; voltage across the inductor leads the current by 90°.

5. Voltage and current phase relationships in a series RL circuit can be illustrated by a vector diagram.



6. The applied voltage is the vector sum of the resistor and inductor voltages.

$$E_a = \sqrt{E_R^2 + E_L^2}$$

NOTE: Pythagorean's theorem is used to find vector sums. The basic formula for Ea can be rearranged to also find the resistor or inductor voltages, as shown below.

$$Ea = \sqrt{(E_R^2) + (E_L^2)} \qquad E_R = \sqrt{(E_a^2) - (E_L^2)} \qquad E_L = \sqrt{(E_a^2) - (E_R^2)}$$

E. Characteristics of impedance in RL circuits

1. The total opposition to current flow offered by both the resistor and inductor in an RL circuit is called impedance.

2. Impedance is expressed in ohms.

3. The applied voltage and the circuit current can be used to determine the impedance according to Ohm's law.

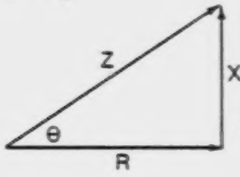
$$\text{Impedance } Z = \frac{E_a}{I_T}$$

4. Impedance of a series RL circuit also can be determined by vector summation of resistance and the inductive reactance.

$$Z = \sqrt{R^2 - R^{L2}}$$

NOTE: Resistance and inductive reactance can also be found using the Pythagorean theorem noted below with the impedance triangle of a series RL circuit.

$$R = \sqrt{Z^2 - X_L^2} \qquad X_L = \sqrt{Z^2 - R^2}$$



Impedance Triangle
of Series RL Circuit

F. Phase shift in RL circuits

1. Phase shift in an RL circuit is a function of the resistance and inductive reactance.

2. The phase angle, theta (θ), of an RL circuit can be found mathematically by the use of trigonometric-based formulas.

$$\tan\theta = \frac{X_L}{R} \qquad \theta = \arctan\frac{X_L}{R} \qquad \theta = \arctan\frac{E_L}{E_R}$$

III. Capacitive AC circuits

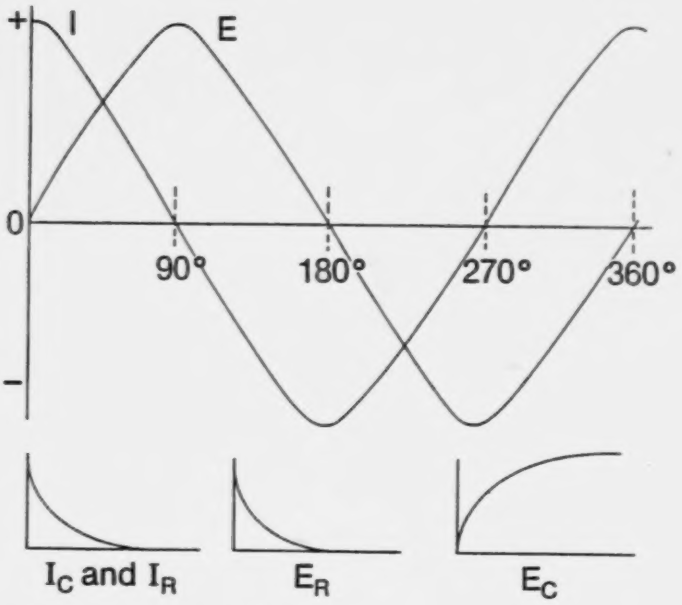
A. Voltage and current relationships

1. When a sine wave is applied to a pure capacitive circuit, a sine-wave voltage will be developed across the capacitor that is equal to and in phase with the applied voltage.

2. The sine-wave current developed in the circuit leads the applied voltage (E_a) and capacitor voltage (E_c) by 90°.

3. When E_a and E_c are at the maximum value of their positive and negative alternations, current in the circuit is zero.

4. When E_R and E_c are at zero, current in the circuit is maximum.



B. Determining capacitive reactance

1. The opposition to AC current flow offered by a capacitor is capacitive reactance.

2. A capacitor's capacitive reactance is determined by the capacitance and the frequency of the applied voltage.

3. Capacitive reactance is inversely proportional to the capacitance and the frequency.

4. Capacitive reactance can be calculated by the formula below.

$$XC = \frac{1}{2\pi fC}$$

NOTE: This formula can also be rearranged to calculate for frequency or capacitance.

5. Capacitive reactances in series are combined like resistances ($Xct = Xc_1 + Xc_2 + Xc_3 + \ldots$).

6. Capacitive reactances in parallel are combined like resistances in parallel using the reciprocal formula ($1/CT = 1/C_1 + 1/C_2 + 1/C_3 + \ldots$).

C. Characteristics of series RC circuits

1. Series RC circuits contain resistors and capacitors connected in series.

2. The voltage drop across the resistor in the series RC circuit is in phase with the current in the circuit.

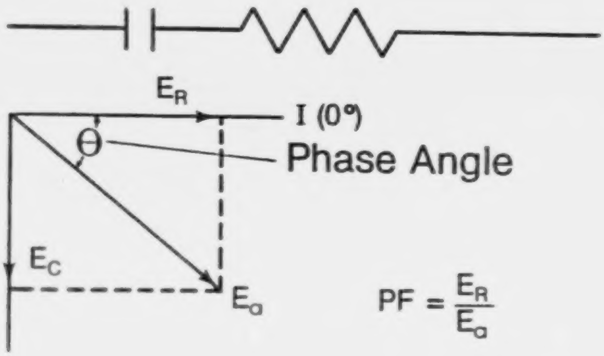
3. Voltage across the capacitor lags the current flowing in the circuit by 90°.

4. Voltages in the series RC circuit can be found through vector summation (Pythagorean theorem) using the following formulas.

$$E_a = \sqrt{(E_R)^2 + (E_c)^2}$$

$$E_R = \sqrt{(E_a)^2 - (E_c)^2}$$

$$E_c = \sqrt{(E_a)^2 - (E_R)^2}$$



$$PF = \frac{E_R}{E_a}$$

$$E_a = I \times Z = \sqrt{(E_a)^2 + (E_R)}^8$$

D. Characteristics of impedance in RC circuits

1. Impedance is the total opposition to current flow in a resistive-capacitive AC circuit.

2. Impedance is expressed in ohms.

3. The impedance of an RC circuit can be calculated by dividing applied voltage by total circuit current.

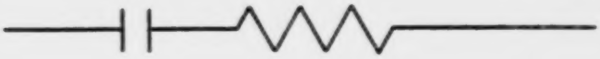
$$\text{Impedance } Z = \frac{E_a}{I_T}$$

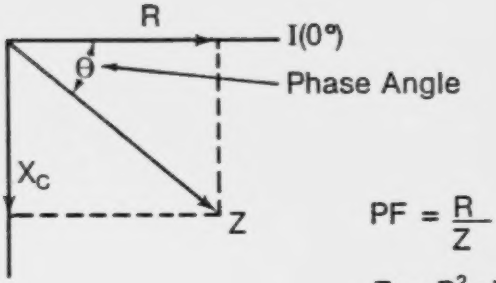
4. An RC circuit's impedance can also be determined by using the Pythagorean's theorem and the resistance and capacitive reactance in the circuit.

$$Z = \sqrt{R^2 + X_c^2}$$

NOTE: Resistance and inductive reactance can also be found by using the Pythagorean theorem as noted below.

$$R = \sqrt{Z^2 - X_c^2} \qquad X_c = \sqrt{Z^2 - R^2}$$





$$PF = \frac{R}{Z}$$

$$Z = R^2 + X_C^2$$

E. Finding the phase angle in an RC circuit

1. The phase angle in an RC circuit can be found by using the following basic trigonometric expression.

   phase angle (θ) = arc tan $\frac{X_C}{R}$

2. If the capacitor and resistor voltage in a series RC circuit are known, the phase can be found with the trigonometric expression below.

   phase angle (θ) = arc tan $\frac{E_c}{E_R}$

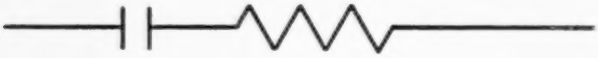
F. Characteristics of power in an AC resistive-capacitive circuit

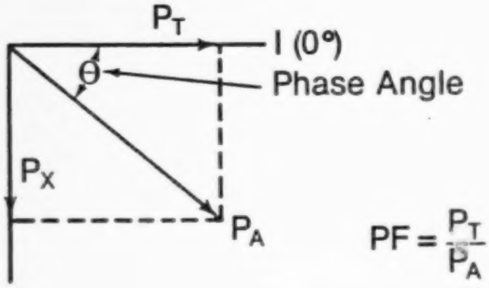
1. True power is dissipated only in the resistance in an RC circuit.

2. Apparent power is the term used to describe the power which "appears" to be consumed in an RC circuit when the power formula P = IE is applied to the circuit.

3. The ratio of true power to apparent power in an AC circuit is referred to as the power factor expressed by the formula below.

$$\text{Power factor (PF)} = \frac{\text{true power}}{\text{apparent power}}$$





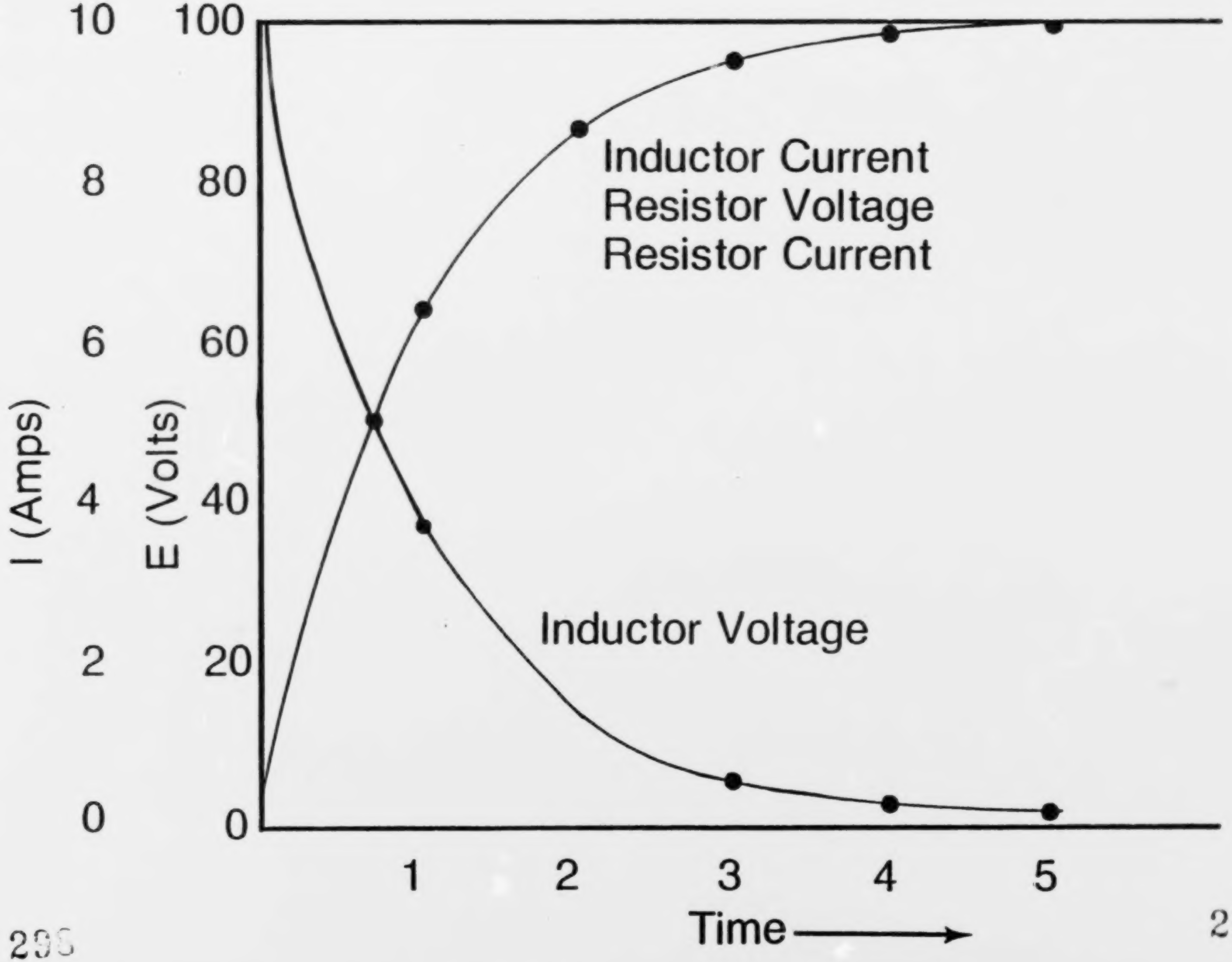
$$PF = \frac{P_T}{P_A}$$

$$P_A = E_A \times I$$

4. The ratio of resistance to impedance is also equal to the cosine of the circuit's phase angle, as expressed in the following formula.

$$\text{Cosine } \theta = \frac{R}{Z} = \text{power factor (PF)}$$

CURRENT AND VOLTAGE RELATIONSHIPS IN AN AC CIRCUIT



AS 1.1

AC INDUCTIVE CIRCUITS

1. Write the formula for computing inductive reactance. __________

2. Inductive reactance is expressed in __________ .

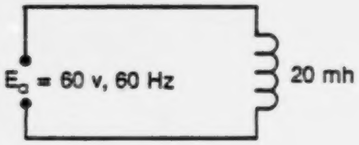
a.	Henrys	c.	Farads
b.	Ohms	d.	Radians

3. If the frequency of the applied voltage of an RL circuit is increased, the inductive reactance (increases/decreases).

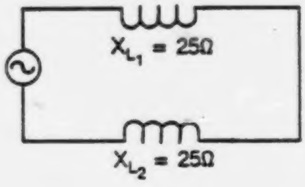
4. If the inductance is increased in a given circuit, the inductive reactance (increases/decreases).

5. For the following circuits, solve for X_L.

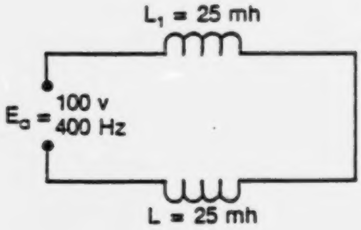
a. X_L = ___________



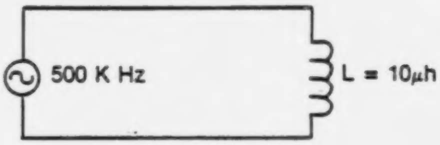
c. X_{LT} = ___________



b. X_L = ___________



d. X_L = ___________



Identify true statements with an "a" and false ones with a "b".

____ 6. Current in a series RL circuit is the same in the inductor as in the resistor at all times.

____ 7. In a purely inductive circuit, current lags applied voltage by 90°.

____ 8. In a practical circuit containing inductance and resistance, current lags voltage by an angle of 0-90°.

____ 9. Voltage across the inductor is always in phase with applied voltage.

____ 10. Voltage across the resistor is always in phase with applied voltage.

____ 11. Voltage across the resistor is always in phase with current flowing through the resistor.

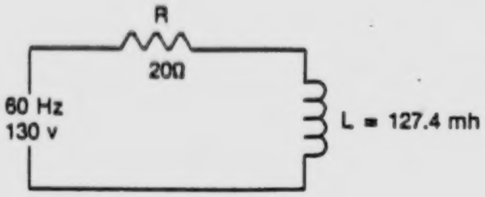
____ 12. Applied voltage is the vector sum of voltage drops across the resistor and inductor.

____ 13. If a power supply provides 100 volts to a circuit having 50Ω of resistance and 50Ω of inductive reactance, there will be 50 volts across the resistor and 50 volts across the inductor.

14. If there are 10Ω of resistance in series with 10Ω of inductive reactance, the circuit impedance will be __________ Ω.

15. If there is a 30V drop across the resistor and a 40V drop across the inductor in a series RL circuit, the applied voltage is __________ V and the cosine of the phase angles is __________ . (Remember that the cosine of the phase angle equals $E_R \div E_a$.)

16. Solve for the following.



a. X_L = __________

b. Z = __________

c. I = __________

d. E_R = __________

e. E_L = __________

17. State the formula for computing Q. __________

18. Two inductors have the same value of L, but one has more resistance in its windings. The one with the most resistance has the (higher/lower) Q.

19. Which of the following statements regarding the Q of inductors is false?

a. All inductors have some resistance.
b. High Q coils usually have relatively little resistance.
c. In general, high Q coils have greater energy storage ability than do low Q coils.
d. Since Q equals X_L divided by R_S, an inductor having a Q of "100" means that it has 100Ω.

20. A coil measured with a DC ohmmeter has 0.5Ω resistance. If the coil has an X_L of 300Ω, Q is __________ .

21. Increasing the angular velocity slightly (increases/decreases) coil Q.

22. An inductor has an internal resistance of 0.5Ω and is rated at 500 mh. If 10V at 60 Hertz is applied, the Q of the inductor is __________.

AS 1.2

AC CAPACITIVE CIRCUITS

1. Write the formula for computing capacitive reactance. X_C = ___________

2. Capacitive reactance is expressed in _________ .

   a. Farads
   b. Henrys
   c. Ohms
   d. Radians

3. If the frequency of applied voltage to an RC circuit is increased, capacitive reactance will (increase/decrease).

4. If capacitance is increased in a given RC circuit, capacitive reactance will (increase/decrease).

5. Angular velocity is decreased by decreasing the _________ .

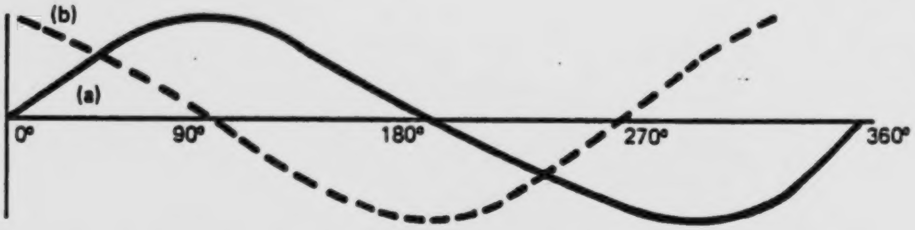
   a. Frequency
   b. Phase angle
   c. Power factor
   d. Capacitance

6. Compute X_c for the following values of C and f.

   a. C = 10,000μF, f = 10 Hz X_c = ____________

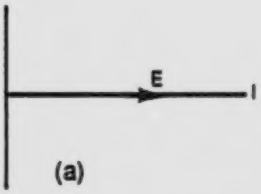
   b. C = 10μF, f = 60 Hz X_c = ____________

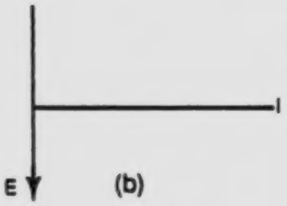
7. At what frequency would a 0.05μF capacitor have 40Ω of capacitive reactance? ______________

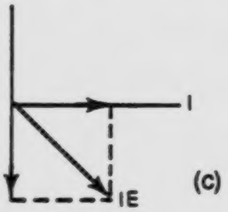


8. a. Which curve from the chart above represents AC current in a capacitive circuit? ____________

   b. Which curve from the chart above represents AC voltage in a capacitive circuit? ____________







9. a. Which of the above diagrams represents a purely capacitive AC circuit? __________

b. Which of the above diagrams represents a purely resistive AC circuit? ___________

c. Which of the above diagrams represents a circuit with R and C? ____

10. Explain what is meant when a circuit has a power factor of 1.

Mark true statements concerning RC circuits with an "a" and false ones with a "b".

____ 11. The current in a series RC circuit is the same in the resistor as in the capacitor when AC voltage is applied.

____ 12. Voltage in a series RC circuit is the same across the resistor as across the capacitor when AC voltage is applied.

____ 13. Current leads voltage by 90° in a purely capacitive circuit.

____ 14. Current lags voltage by 90° in a purely capacitive circuit.

____ 15. Current is in phase with voltage in a purely resistive circuit.

____ 16. Voltage lags current by 90° in a purely resistive circuit.

____ 17. Voltage across the resistor is always in phase with applied voltage in an RC circuit.

____ 18. If 100 volts is applied to a circuit having 50Ω of resistance and 50Ω of capacitive reactance, there will be a 50-volt drop across the resistor and a 50-volt drop across the capacitor.

19. If there are 40Ω of resistance in series with 40Ω of capacitive reactance, the circuit impedance, Z, equals ____________ Ω.

20. If there is a 40 volt drop across the resistor and a 30 volt drop across the capacitor in an RC circuit, the applied voltage is ____________ volts and the phase angle is ______________ degrees.

Solve for the following in the circuit below.

21. X_C = _______

22. Z = _______

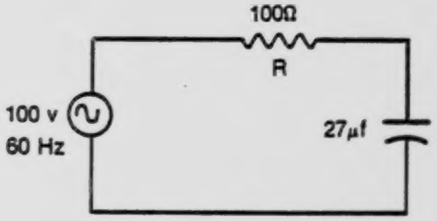
23. I = _______

24. E_R = _______

25. E_C = _______

26. θ = _______

27. PF = _______



ANSWERS TO AS 1.1

1. $X_L = 2\pi fL$
2. b
3. increases
4. increases
5. a. 7.54Ω
   b. 125.7Ω
   c. 50Ω
   d. 31.4Ω
6. a
7. a
8. a
9. b
10. b
11. a
12. a
13. b
14. 14.1Ω
15. 50 volts; 30/50 or .6
16. a. 48Ω
    b. 52Ω
    c. 2.5Ω
    d. 50 volts
    e. 120 volts
17. $Q = X_L + R$
18. lower
19. d
20. 600
21. increases
22. 377

ANSWERS TO AS 1.2

1. $X_C = .5\ \pi fc$
2. c
3. decrease
4. decrease
5. a
6. a. 1.59Ω
   b. 265Ω
7. 79,500 Hz
8. a, b
9. b, a, c
10. A power factor of 1 means that the circuit is a resistive circuit.
11. a
12. b
13. a
14. b
15. a
16. a
17. b
18. b
19. 56.6Ω
20. 50 volts; 36.9° (arc cos 40/50)
21. 98.1Ω
22. 140Ω
23. 714Ω
24. 71.4V
25. 70V
26. 45.6°
27. 0.699

DETERMINE EFFECT OF INDUCTANCE IN AC CIRCUITS

Equipment:

Filter choke approximately 2H or larger
75Ω, 1 watt resistor
DC and AC milliammeters
Multimeter
AC and DC power supplies

	Procedure:	Evaluation 3	2	1	N
1.	Connect the 75Ω resistor and DC ammeter in series with the DC power supply.	—	—	—	—
2.	Adjust the voltage until there are 5V across the resistor.	—	—	—	—
3.	Record the ammeter indication; then compute R_{DC}.	—	—	—	—
	NOTE: $R_{DC} = E \div I$				
4.	Connect the 75Ω resistor and AC ammeter in series with the AC power supply.	—	—	—	—
5.	Adjust the voltage until there are 5V across the resistor. Record the current from the ammeter and compute R_{AC}.	—	—	—	—
	NOTE: $R_{AC} = E \div I$				
6.	Compare R_{DC} and R_{AC} and explain any differences.	—	—	—	—
7.	Connect the choke (inductor) and DC ammeter in series with DC power supply.	—	—	—	—
8.	Adjust the DC power supply until there are 5V across the choke. Read the current indication on the ammeter and compute $Z_{L(DC)}$.	—	—	—	—
	NOTE: $Z_{L(DC)} = E_L \div I_L$				
9.	Repeat step 8 using the AC ammeter and AC power supply; compute $Z_{L(AC)}$.	—	—	—	—
	NOTE: $Z_{L(AC)} = E_L \div I_L$				
10.	Compare the current recorded in step 8 with that recorded in step 9 and explain any differences.	—	—	—	—
11.	Use the filter choke value (Henrys) and the voltage frequency to compute X_L.	—	—	—	—
12.	Compare the computed X_L (step 11) with the DC impedance (step 8) and the AC impedance (step 9). Explain any differences observed.	—	—	—	—
13.	Return equipment and materials to the proper storage area.	—	—	—	—

Average of above evaluation* ___ ___ ___ ___

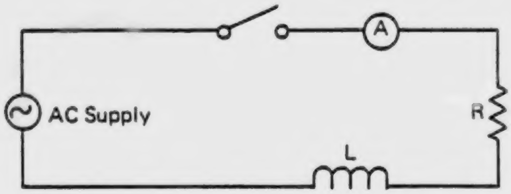
*This average is the student's partial evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

DETERMINE VALUES OF AN OPERATING RL CIRCUIT

Equipment:

Filter choke approximately 2H or larger
Resistor, 750Ω, 5 watts
AC power supply
AC ammeter
Multimeter
Switch

		Evaluation			
Procedure:		3	2	1	N
1.	Measure and record the resistance of the inductor (filter choke) with the ohmmeter. __________ NOTE: This is the DC resistance (R_{DC}) of the coil.	—	—	—	—
2.	Measure and record the value of the 750Ω resistor. __________	—	—	—	—
3.	Connect the circuit as shown in the following schematic.	—	—	—	—

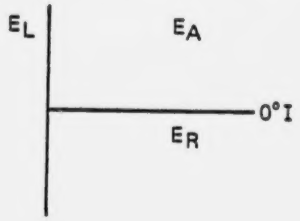


		3	2	1	N
4.	Connect an AC voltmeter across the AC power supply; close the switch and adjust the AC input until the meter indicates 30 volts.	—	—	—	—
5.	Read and record the voltage across R(E_R). __________	—	—	—	—
6.	Read and record the voltage across L(E_L). __________	—	—	—	—
7.	Read and record the applied voltage (across both R and L). __________	—	—	—	—
8.	Read and record the current flowing in the circuit (I). __________	—	—	—	—
9.	Compute the value of X_L. __________	—	—	—	—
10.	Add the coil's DC resistance (step 1) and the resistor value (step 2); then multiply this value by the circuit current and compare the result with the applied voltage (E_a) observed in step 7. __________	—	—	—	—
11.	Add E_R (step 5) and E_L (step 6). __________ Compare with E_a (step 7).	—	—	—	—
12.	Repeat step 11 but use the formula below.	—	—	—	—

$$E_a = \sqrt{E_R^2 + E_L^2}$$

13. Multiply the current (step 8) and the computed value of X_L (step 9). ________ Compare the result with E_L (step 7). — — — —

14. Make a vector diagram to scale showing the values of E_R, E_L and E_a, letting E_a be the hypotenuse of the right triangle formed by the sides E_R and E_L. Explain any differences. — — — —



15. Discuss and explain differences observed with the instructor. — — — —

16. Return equipment and materials to the proper storage area. — — — —

Average of above evaluation* — — — —

*This average is the student's partial evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

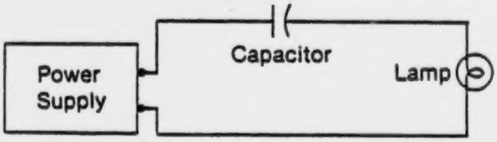
JS 1.3

DETERMINE EFFECT OF AC AND DC ON CAPACITORS

Equipment:

DC power supply, 0-40V
AC power supply, 0-40V
Electrolytic capacitor, approximately 10μF, 100WV$_{DC}$ (Two 5μF capacitors can be used.)
Miniature lamp and holder

	Evaluation			
Procedure:	3	2	1	N
1. Connect the circuit as shown below using the DC power supply, capacitor and lamp.	___	___	___	___



2. Turn on the power supply and adjust to 20 volts DC. Observe whether or not the lamp lights.	___	___	___	___
3. Return the voltage to zero. Turn off the power supply. Disconnect the circuit from the DC power supply.	___	___	___	___
4. Connect the circuit to the AC power supply.	___	___	___	___
5. Turn on the AC power supply and adjust to 20V$_{AC}$. Observe whether or not the lamp lights and compare with results obtained in step 2.	___	___	___	___
6. Return the voltage to zero. Disconnect the circuit.	___	___	___	___
7. Return equipment and materials to proper storage area.	___	___	___	___
Average of above evaluation*	___	___	___	___

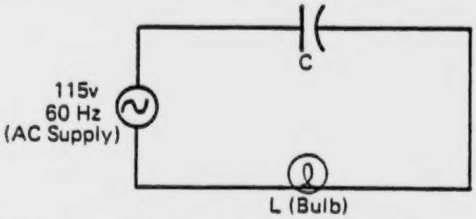
*This average is the student's partial evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

DETERMINE EFFECT OF CAPACITIVE REACTANCE IN AC CIRCUITS

Equipment:

Two capacitors: 8μF and 1μF, 450 WV_{DC}
One 15W, 120V light bulb and holder
Multimeter
AC power supply

Procedure:	Evaluation 3	2	1	N
1. Connect the circuit as shown below using the 8μF capacitor.	___	___	___	___



Procedure:	Evaluation 3	2	1	N
2. Turn on the power and observe bulb brightness.	___	___	___	___
3. Measure and record E_a, E_C and E_L (voltage across bulb or load). __________	___	___	___	___
4. Compute $(E_C)^2$ plus $(E_L)^2$; obtain square root; then compare with measured value of E_a.	___	___	___	___
5. Substitute the 1μF capacitor for the 8μF capacitor; then repeat steps 2, 3 and 4.	___	___	___	___
6. Discuss the relative amounts of capacitive reactance of the 8μF and 1μF capacitor. (Which has the most opposition to the flow of current?)	___	___	___	___
7. Discuss the differences observed between measured and calculated values of E_a.	___	___	___	___
8. Return equipment and materials to proper storage area.	___	___	___	___
Average of above evaluation*	___	___	___	___

*This average is the student's partial evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

DETERMINE CAPACITIVE REACTANCE AND IMPEDANCE IN RC CIRCUITS

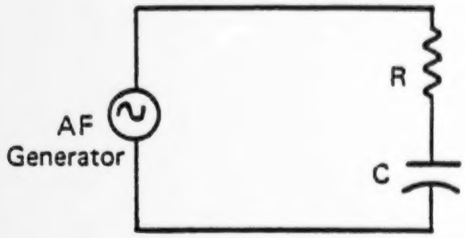
Equipment:

A.F. generator
Capacitor, 0.3μF
Resistor, 1000Ω, 1 watt
Multimeter
Graph paper and protractor

Evaluation
3 2 1 N

Procedure:

1. Connect the circuit shown in the following schematic. — — — —



2. Set the A.F. generator to a frequency of 150 Hz and adjust the output to one volt; then measure E_R and E_C and record in the data table below. — — — —
3. Set the A.F. generator to the next frequency listed in the data table. Adjust the output to one volt; then measure and record E_R and E_C. — — — —
4. Repeat step 3 for each listed frequency. — — — —

Data Table

			I	Z	X_C	X_C	Z	Θ	Θ	PF
Frequency	E_R	E_C	E_R/R	$E_A I$	$1/2\pi fC$	$E_C/1$	Graph	Graph	Arc cos E_R/E_A	Cos Θ
150 Hz										
250 Hz										
450 Hz										
900 Hz										
1100 Hz										

5. Compute I (E_R ÷ 10,000) for each frequency and enter into table. — — — —
6. Compute Z (E_a ÷ I) for each frequency and enter into table. — — — —
7. Compute X_C by using the formula 1 ÷ C for each frequency. — — — —
8. Compute X_C (E_C ÷ I), enter into table and compare results with step 7. — — — —
9. Using X_C of step 8 and 1000Ω for R, draw a graph showing the vector relationships. Measure the value of Z on the graph. — — — —

10. Compare the results of step 9 with step 6. ___ ___ ___ ___

11. Measure the phase angle, θ, on the graph and enter. ___ ___ ___ ___

12. Compute the phase angle, θ, by obtaining the angle whose cosine is E_R + E_a. ___ ___ ___ ___

13. Compute and enter the power factor. ___ ___ ___ ___

14. Calculate the frequency necessary to have X_C equal to 1000Ω. ___ ___ ___ ___

15. Set the A.F. generator to this frequency and enter all information called for into the data table. ___ ___ ___ ___

16. Analyze and discuss results with the instructor. ___ ___ ___ ___

17. Return equipment and materials to proper storage area. ___ ___ ___ ___

Average of above evaluation* ___ ___ ___ ___

*This job sheet, averaged with JS 1.1-1.4, is the student's final evaluation for competency B11: Solve AC network problems utilizing appropriate theorems and laws.

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IX: REACTIVE AND RESONANT CIRCUITS

LESSON 2: RESONANT CIRCUITS

I. Terms and definitions

   A. Attenuate--to reduce amplitude of a signal

   B. Filter--a circuit designed to allow certain frequencies to be stopped or passed

   C. Resonant circuit--contains both inductive and capacitive components. Its frequency causes the reactance of both components to be equal.

   D. Cut-off frequency--the one-half power point (equal to the point where the voltage output drops to 70% of the input value) of a filter's output. Past this frequency, the filter is considered to have "cut off" the input signal.

   E. Low-pass filter--passes lower frequencies and attenuates higher frequencies past its cut-off point

   F. High-pass filter--passes higher frequencies and attenuates lower frequencies past its cut-off point

   G. Band-pass filter--passes only a specific range of frequencies. This filter will have two cut-off frequencies and a band-width rating.

   H. Band-stop filter--(also called a notch or reject filter and a trap) filter that rejects a specific range of frequencies. This filter will have two cut-off frequencies and a band-width rating.

   I. Band width--range of frequencies centered around a resonant frequency passed or rejected by a filter

   J. Pi filter--components look like the Greek character π

   K. T filter--components look like the letter T

   L. L filter--components look like the letter L

II. RCL circuits

   A. Characteristics of series RCL circuits

      1. Series RCL circuits contain resistance (R), capacitance (C) and inductance (L) connected in series.

      2. Total reactance in a series RCL circuit is a combination of X_L and X_C.

         a. Net reactance X_T equals the difference between X_L and X_C.

         b. When the inductive reactance is greater than the capacitive reactance, the circuit appears inductive.

         c. When the capacitive reactance is greater than the inductive reactance, the circuit appears capacitive.

   d. When inductive and capacitive reactance are equal, the circuit appears resistive (resonant).

3. Impedance in an RCL circuit can be found by using the following formula. (HO 2.1)

$$Z = \sqrt{R^2 + X_T^2}$$

4. Current is common to all components in a series RCL circuit, and the phase of voltages within the circuit can be referenced to the common current.

   a. Voltage across the resistance (V_R) is in phase with the current.

   b. Voltage across the inductor (V_L) leads the current by 90°.

   c. Voltage across the capacitor (V_C) lags the current by 90°.

   d. Reactive voltage (V_T) is the vector sum of the inductive voltage (V_L) and capacitive (V_C) voltages.

   e. The vector sum of the resistive voltage and the reactive voltage equals the applied voltage.

$$E_a = \sqrt{V_R^2 + V_X^2}$$

B. Resonant characteristics of series RCL circuits (TM 2.1)

1. Resonance in a series RCL circuit occurs when the inductive effect equals the capacitive effect.

   NOTE: Resonance is also commonly stated as that point at which inductive reactance equals capacitive reactance.

   a. Impedance of the circuit is at its minimum value at resonance.

   b. Circuit current is at its maximum level at resonance.

   c. At resonance, the phase angle between voltage and current is zero.

   d. Inductive voltage (V_L) and capacitive voltage (V_C) are equal at resonance and larger in value than applied voltage.

2. Resonant frequency (f_r) of a series RCL circuit can be calculated using the formula below.

$$f_r = \frac{1}{2\pi \sqrt{LC}}$$

   a. Increasing inductance or capacitance decreases the resonant frequency.

   b. Decreasing inductance or capacitance increases the resonant frequency.

3. Circuit Q is a figure of quality for a series resonant circuit and is the ratio of the reactance at resonance to the series AC resistance.

$$Q = \frac{X}{R}$$

NOTE: Since $X_L = X_C$ at resonance, either value can be used for X in the formula.

4. Band width (BW) of a series resonant circuit is measured between the half-power points of the circuit. BW can be calculated by dividing resonant frequency by the circuit Q.

$$BW = \frac{f_r}{Q}$$

C. Characteristics of parallel RCL circuits (TM 2.2, HO 2.2)

1. A parallel RCL circuit is a circuit in which resistance (R), capacitance (C) and inductance (L) are connected in parallel.

2. Voltage is the same across all branches of a parallel RCL circuit, and the phase of the individual branch currents can be referenced to it.

    a. Current through the resistive branch is in phase with voltage and can be found using the formula $I = E_a + R$.

    b. Current through the inductive branch of the parallel RCL circuit lags voltage by 90° and can be found using the formula $I = E_a + X_L$.

    c. Current through the capacitive branch of the parallel RCL circuit leads voltage by 90° and can be found using the formula $I = E_a + X_C$.

3. Reactive current (I_X) is the difference between current in the inductive branch (I_L) and the capacitive branch (I_C).

4. Total current in a parallel RCL circuit is the vector sum of the resistive current (I_R) and the reactive current (I_R).

$$I_T = \sqrt{I_R^2 + I_X^2}$$

5. Impedance in a parallel RCL circuit can be found by dividing the applied voltage by the total current.

$$Z = \frac{E_a}{I_T}$$

D. Resonant characteristics of a parallel RCL circuit

1. Resonance in a parallel RCL circuit occurs when the inductive effects equal the capacitive effects (tank circuit).

    a. Impedance of the parallel RCL circuit is maximum at resonance and can be calculated using the formula $Z = E_a + I_Z$.

    b. Current is at minimum value at resonance and equals the resistive current.

    c. The phase between the applied voltage and the total current is zero.

2. Resonant frequency (f_r) of a parallel RCL circuit can be calculated using the formula below.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

3. The Q of a parallel resonant circuit can be calculated by dividing the inductive reactance by the total AC resistance.

$$Q = \frac{X_L}{R}$$

4. The band width (BW) of a parallel resonant circuit can be calculated by dividing the resonant frequency by the Q.

$$BW = \frac{f_r}{Q}$$

III. Low- and high-pass filters

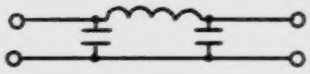
A. Filter cut-off frequency

1. The frequency at which the output drops to one-half of the input power

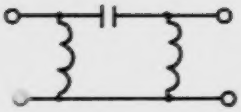
2. Also the point where voltage drops to 70% of the input

B. Pi filters are components in the shape of the Greek letter π.

1. Low pass

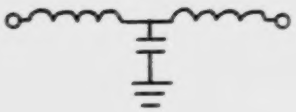


2. High pass

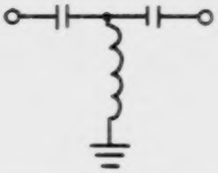


C. T filters are components in the shape of the letter T.

1. Low pass

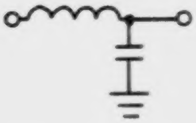


2. High pass

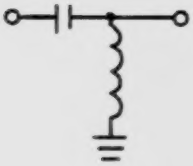


D. L filters are components in the shape of the letter L.

1. Low pass



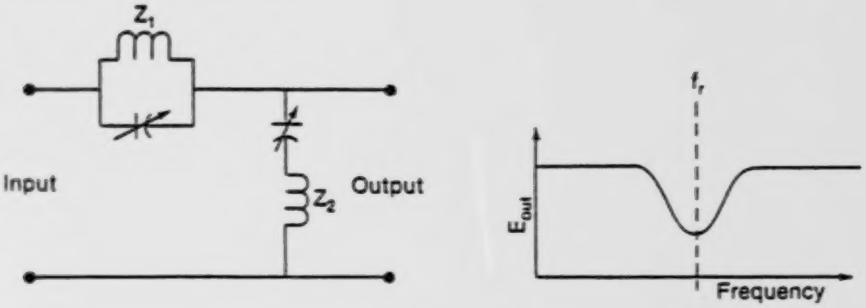
2. High pass



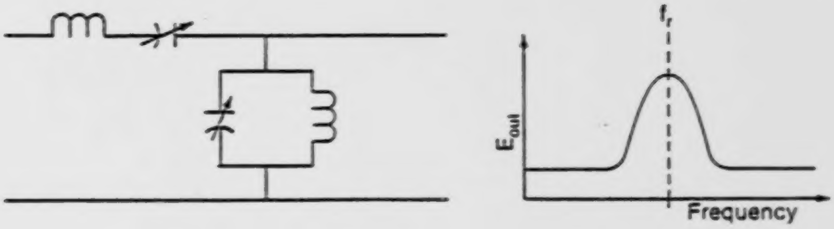
E. Applications of resonant circuits

1. Resonant circuits can be used as filters to accept or reject a specified band of frequencies.

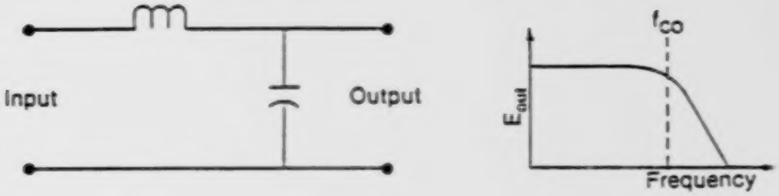
2. A band-stop filter is designed to stop a band of frequencies while allowing all other frequencies to pass to the output.


Z_1
Input
Z_2
Output
f_r
E_{out}
Frequency

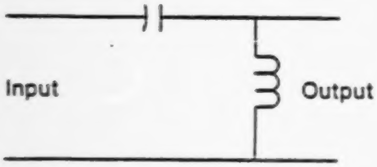
3. A band-pass filter may be designed to pass a certain band of frequencies and stop all other frequencies.

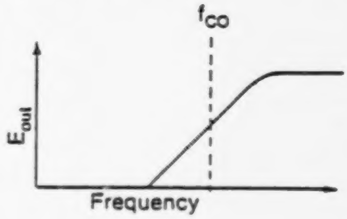

f_r
E_{out}
Frequency

4. A low-pass filter is designed to pass all frequencies below the cut-off frequency (f) and attenuate all frequencies above the cut-off frequency.

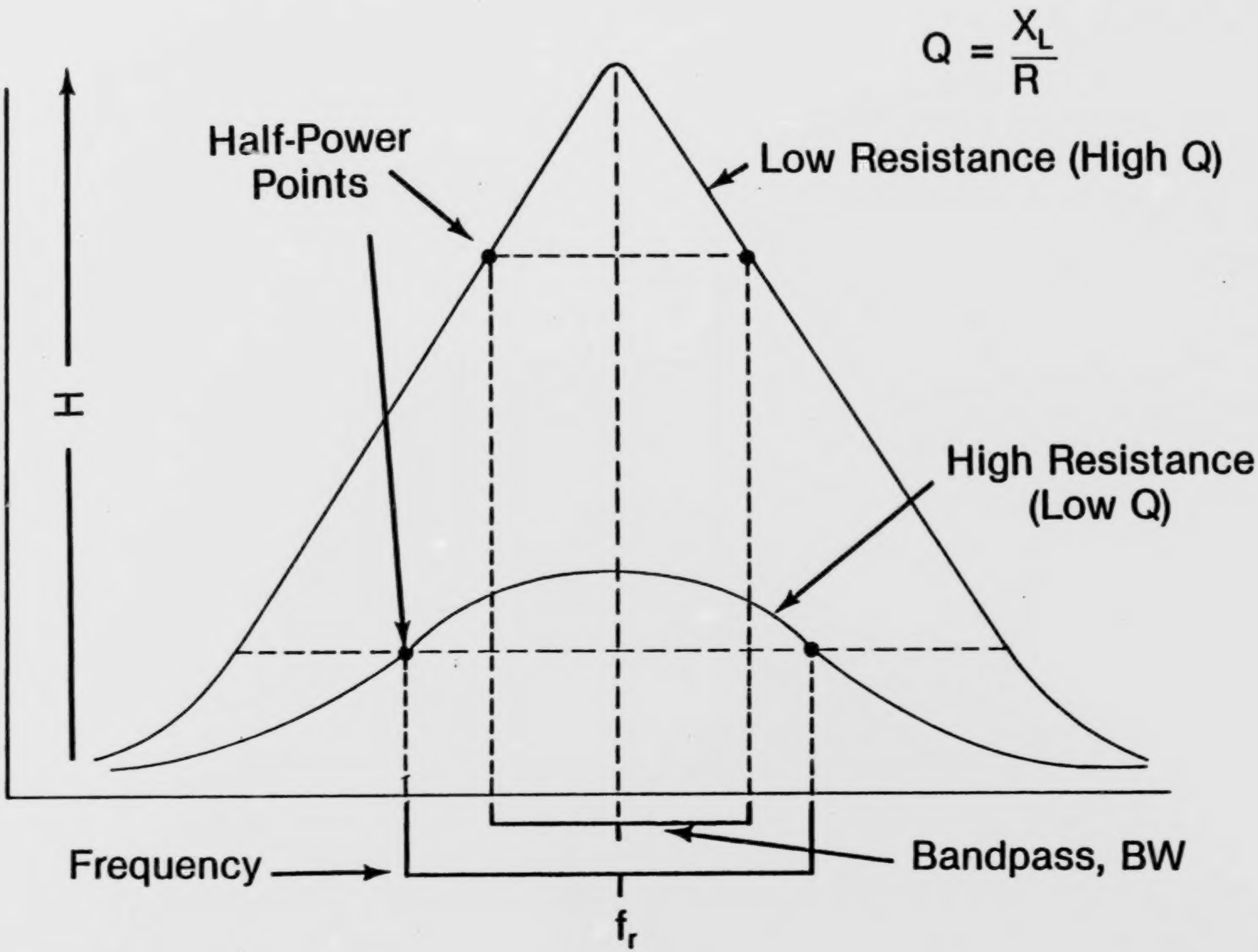

Input
Output
f_{co}
E_{out}
Frequency

5. A high-pass filter may be designed to pass all frequencies above the cut-off frequency and attenuate all frequencies below the cut-off frequency.





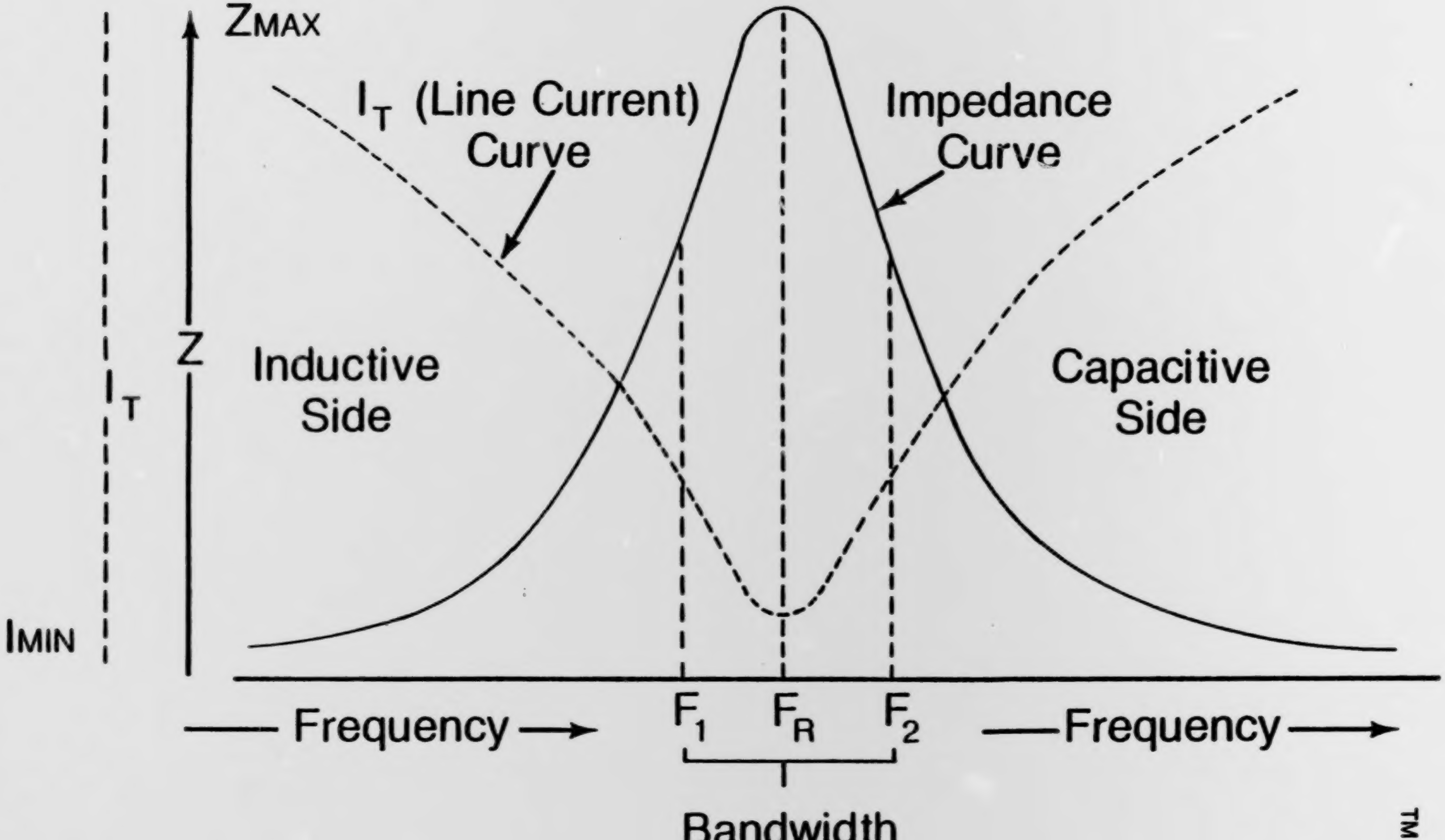
RESONANT CURVES



$$Q = \frac{X_L}{R}$$

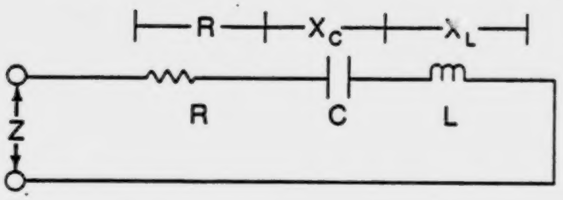
Half-Power Points
Low Resistance (High Q)
High Resistance (Low Q)
H
Frequency
Bandpass, BW
f_r

TUNED PARALLEL CIRCUIT CURVES

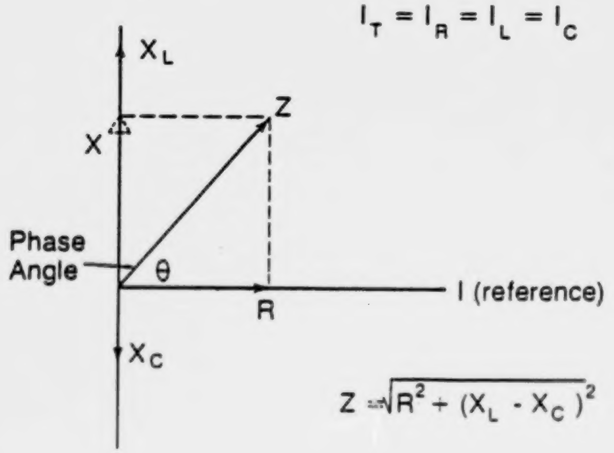


IMPEDANCE, VOLTAGE AND RESONANCE RELATIONSHIPS IN SERIES RCL CIRCUITS

Impedance

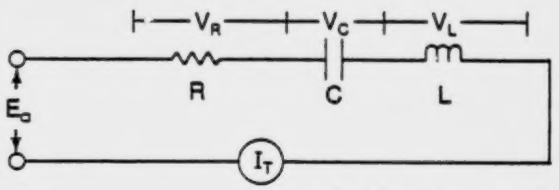


$I_T = I_R = I_L = I_C$

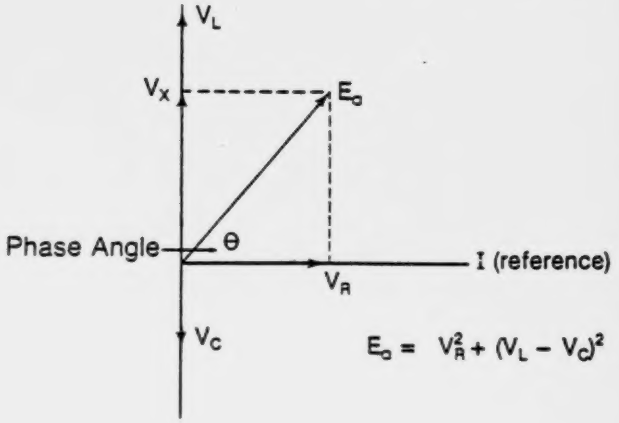

X_L
Z
X
Phase Angle
θ
R
I (reference)
X_C

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

Voltage

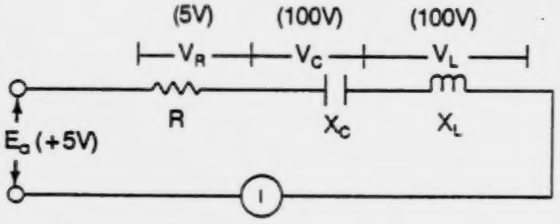

V_R
V_C
V_L
E_a
R
C
L
I_T

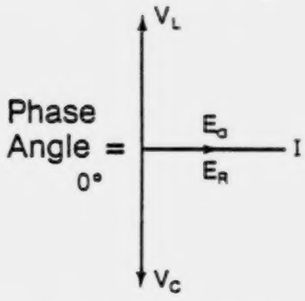
$I_T \quad I_T = I_R = I_C = I_L$

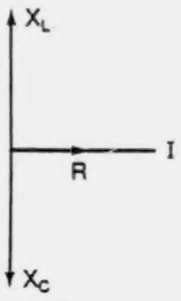

V_L
V_X
E_a
Phase Angle
θ
I (reference)
V_R
V_C

$E_a = V_R^2 + (V_L - V_C)^2$

Resonance


(5V)
(100V)
(100V)
V_R
V_C
V_L
R
X_C
X_L
E_a (+5V)
I

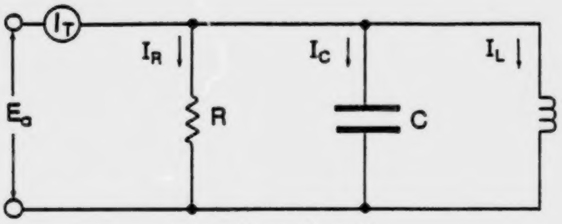

V_L
Phase Angle = 0°
E_a
E_R
I
V_C



$E_L = E_C ; E_a = E_R \qquad X_C = X_L ; Z = R$

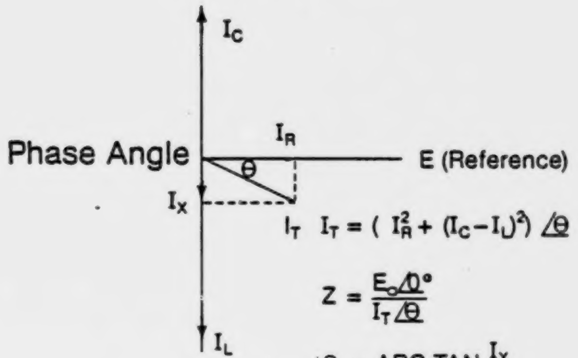
CURRENT AND RESONANCE RELATIONSHIPS IN PARALLEL RCL CIRCUITS

Current



I_T
I_R
I_C
I_L
E_a
R
C

$E_a = V_R = V_C = V_L$



I_C
Phase Angle
I_R
θ
E (Reference)
I_X
I_T
I_L

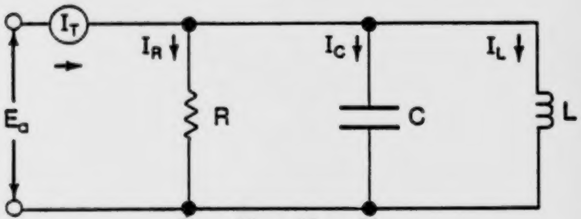
$I_T = (I_R^2 + (I_C - I_L)^2) \angle\theta$

$Z = \frac{E_a \angle 0°}{I_T \angle\theta}$

$\theta = \text{ARC TAN} \frac{I_X}{I_R}$

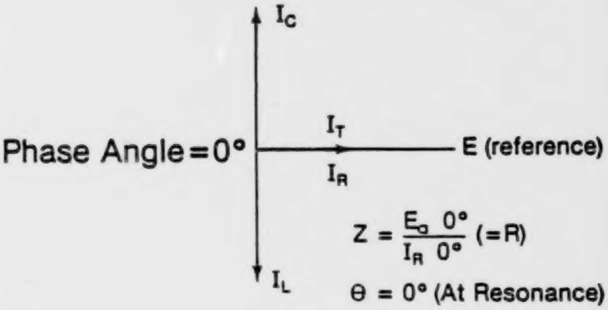
$\theta = \text{ARC COS} \frac{I_R}{I_T}$

Resonance



I_T
I_R
I_C
I_L
E_a
R
C
L

$E_a = V_R = V_C = V_L$



I_C
Phase Angle = 0°
I_T
E (reference)
I_R
I_L

$Z = \frac{E_a \; 0°}{I_R \; 0°}$ (=R)

$\theta = 0°$ (At Resonance)

$I_C = I_L$

$I_T = I_R$

$Z = R$

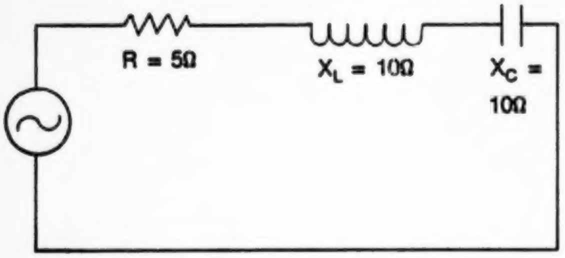
SERIES RESONANT CIRCUITS

Fill in the blank to complete the statement.

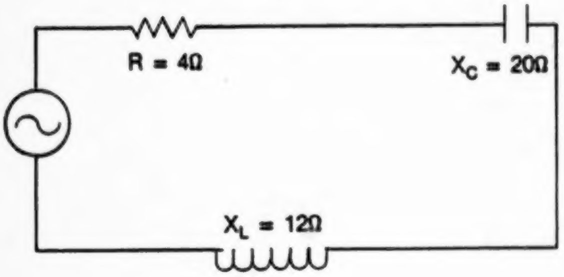
1. The formula for computing total reactance, X_T, is ________________ .
2. If X_L is 10Ω and X_C is 5Ω, X_T equals ____________Ω and the circuit is (capacitive/inductive).
3. If X_L is 5Ω and X_C is 10Ω, X_T equals ____________Ω and the circuit is (capacitive/inductive).
4. The formula used to compute inductive reactance, X_L, is ____________ .
5. The formula used to compute capacitive reactance, X_C, is ___________ .
6. Capacitance is measured in ___________ (units) and capacitive reactance is measured in __________ .
7. Inductance is measured in ______ , and inductive reactance in _____ .
8. A 1 mH coil, in series with a 5F capacitor, causes a circuit to be (inductive/capacitive) at 3 Hz and (inductive/capacitive) at 1KHz.
9. Inductive reactance varies (directly/inversely) with frequency.
10. Capacitive reactance varies (directly/inversely) with frequency.

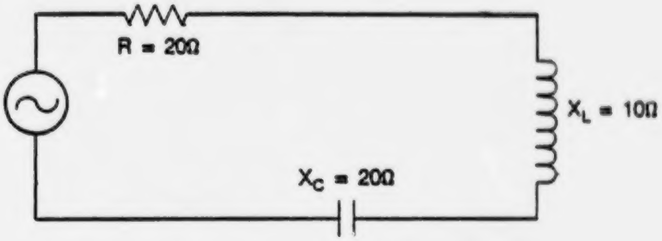
For the next three circuits, compute answers and make sketches of the impedance triangles.

11. The impedance of the circuit below is ____________ .

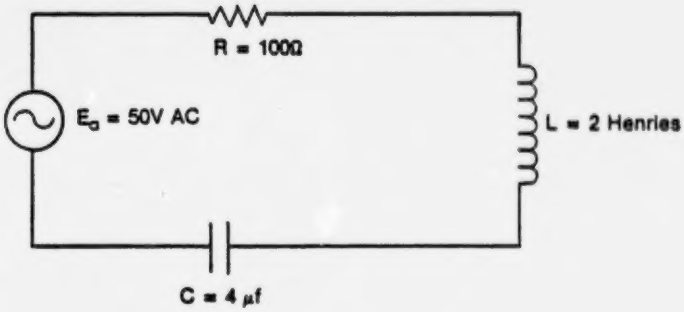


12. The impedance of the circuit below is ____________ .




R = 20Ω
X_L = 10Ω
X_C = 20Ω

Solve for the specified values using the circuit schematic below. Be sure to include units of measurement.


R = 100Ω
E_a = 50V AC
L = 2 Henries
C = 4 μf

14. Resonant frequency, f_r, = ____________________

15. Total current at resonance = ____________________

16. Inductive reactance, X_L, = ____________________

17. Capacitive reactance, X_C, = ____________________

18. Inductive voltage drop, V_L, = ____________________

19. Capacitive voltage drop, V_C, = ____________________

20. Resistive voltage drop, V_R, = ____________________

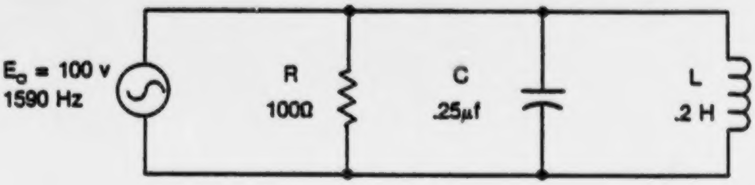
21. Power dissipated in the circuit, P, = ________________

22. The Q of the circuit is ____________________.

23. The band width, BW, of the circuit is ____________________.

PARALLEL RESONANT CIRCUITS

Solve for the indicated parameters of the circuit below. A 100Ω resistor, a 0.2 Henry inductor and a 0.25μF capacitor are connected in parallel across a source voltage of 100 volts at 1590Hz.



1. X_L = ____________
2. X_C = ____________
3. I_R = ____________
4. I_C = ____________
5. I_L = ____________
6. I_T = ____________
7. Z = ____________
8. P_T = ____________
9. P_A = ____________
10. Power factor, PF = ____________
11. Phase angle, θ = ____________
12. In a parallel circuit, impedance is a function of the ____________ of the voltage applied.
13. At parallel resonance, __________ .

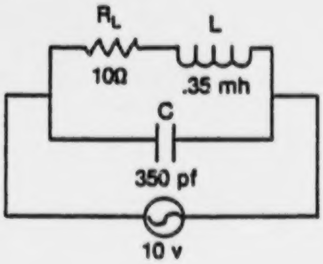
    a. Impedance is minimum
    b. Impedance is maximum
    c. Current is minimum
    d. Current is maximum

14. Frequencies higher than the resonant frequency of a parallel RCL circuit causes more current to be in the __________ branch.

    a. Capacitive
    b. Inductive

15. The formula for computing resonant frequency is ____________________ .

An inductor and capacitor are connected as shown in the schematic below, and 10 volts are applied. Solve for the indicated parameters.



16. Resonant frequency, F_R, = ________________

17. The Q of the circuit = ____________________

18. I_C (also called tank current) = ___________

19. I_T (use Q and I_C) = ______________________

20. Impedance, Z, = _________________________

21. Power consumed, P_T, = ___________________

22. Band width, BW, = _______________________

ANSWERS TO AS 2.1

1. $X_L - X_C$
2. +5, inductive
3. -5, capacitive
4. $2\pi FL$
5. $\frac{1}{2\pi fc}$
6. farad, ohms
7. Henrys, ohms
8. capacitive, inductive
9. directly
10. inversely
11. 5Ω
12. 8.94Ω
13. 22.36Ω
14. 57 Hz
15. 0.5 amps
16. 713Ω
17. 713Ω
18. 356.5 volts
19. 356.5 volts
20. 50 volts
21. 25 watts
22. 7.13
23. 7.96 or 8 Hz

ANSWERS TO AS 2.2

1. 1,997Ω
2. 400Ω
3. 1 amp
4. 0.25 amp
5. 0.05 amp
6. 1.02 amp
7. 98Ω
8. 100 watts
9. 102 VA
10. 0.98
11. 11.3 degrees leading
12. frequency
13. c
14. a
15. $f_r = \frac{1}{2\pi\sqrt{LC}}$
16. 455 KHz
17. Q = 100
18. 10µ
19. 0.1µ
20. 10KΩ
21. 0.001 watt
22. 4.55 KHz

JS 2.1

DETERMINE RESONANCE IN A SERIES RCL CIRCUIT

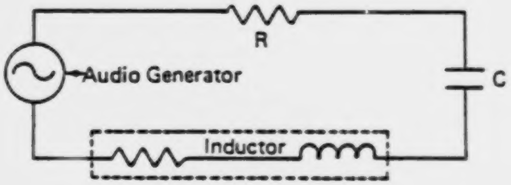
Equipment:

Audio generator
Oscilloscope
Multimeter
1μF capacitor
1H inductor
100Ω resistor
Linear graph paper

Procedure: Evaluation 3 2 1 N

1. Using the ohmmeter, measure resistance of the 100Ω resistor and the inductor. Record these measurements in the data table on this job sheet. ___ ___ ___ ___

2. Connect the resistor, inductor and capacitor in series to the audio generator as follows. ___ ___ ___ ___



3. Use the values of the capacitor and inductor to compute the expected resonant frequency of this circuit. ___ ___ ___ ___

4. Connect the multimeter across the generator output terminals and set the generator for maximum voltage at 100 Hz. Vary the generator frequency around the value computed in step 3 until the voltage output is at a minimum; note the voltage output. ___ ___ ___ ___

5. Choose a generator voltage slightly less than the minimum noted above and set the generator to this value. This will be the applied voltage, E_a, for the following steps and must be maintained at all times. ___ ___ ___ ___

6. Remove the multimeter and connect the oscilloscope across the generator output terminals. Observe carefully the indication on the oscilloscope--you must maintain a constant E_a (as indicated on the oscilloscope) for the remaining steps. ___ ___ ___ ___

7. Connect the multimeter across the 100Ω resistor. Read and record the voltage across the resistor, V_R, for generator frequencies on the data table. Be sure that the applied voltage, E_A, is the same for all of these frequencies. ____ ____ ____ ____

Frequency:	80 Hz	100	120	140	160	180	200	220	240	F_r = ____
V_R										
I_T										
Z										

8. Adjust the generator to the frequency that gives the maximum V_R reading; be sure that E_a is at its correct value. Record this resonant frequency of the circuit, F_O, along with its corresponding V_R in the data table. ____ ____ ____ ____

9. With the generator at F_O and E_a at is proper value, connect the oscilloscope across the resistor and observe the waveform. ____ ____ ____ ____

10. Move both leads in sequence and connect them across the capacitor; observe the waveform. ____ ____ ____ ____

    NOTE: Equipment grounds can cause improper indications.

11. Repeat for the inductor. Be sure to watch for shifts in both amplitude and horizontal movement. ____ ____ ____ ____

12. Set the generator to 100 Hz and E_a to its correct value. Using the oscilloscope, observe the voltage waveforms across the resistor, capacitor and inductor. ____ ____ ____ ____

13. Turn the generator off. ____ ____ ____ ____

14. Using Ohm's law, compute the circuit current, I_T, for each frequency. Record each computed value in the data table. ($I_T = V_R + R$) ____ ____ ____ ____

15. Using Ohm's law, compute the circuit impedance, Z, for each frequency. Record each computed value in the data table. ($Z = E_a + I_T$) ____ ____ ____ ____

16. Prepare a graph with the various frequency settings listed in the data table on the horizontal axis. Plot the corresponding values of I_T on the vertical axis. Draw a smooth curve between these points (include F_r). ____ ____ ____ ____

17. Plot the values of Z on the same graph and draw a smooth curve between these points. ____ ____ ____ ____

18. Return equipment and materials to proper storage area. ____ ____ ____ ____

Average of above evaluation* ____ ____ ____ ____

*This average is the student's partial evaluation for competency B20: Test and evaluate filter performance.

Discuss the following.

1. Does the computed resonant frequency, f_r, of step 3 equal the observed resonant frequency, F_O, of step 8? Explain any difference.

2. Why is the generator output voltage in step 4 at a minimum at the resonant frequency? (HINT: Is there any resistance inside the generator?)

3. On the graph, compare the maximum value of I_T and the minimum value of Z. Do these occur at the same frequency?

4. Compare the minimum value of Z with the circuit's total resistance found in step 1. Explain the difference.

5. Why was there such a large difference between the capacitor voltage and the resistor voltage observed in step 9? Were the capacitor voltage and the inductor voltage observed in step 9 equal but opposite in phase?

6. Explain why the inductor voltage was smaller than the capacitor voltage in step 12. How do these voltages differ from those observed in steps 9, 10 and 11?

7. If this circuit was connected between a generator and a load, what frequency would be passed most easily? What impedance would be presented? How much greater would the impedance be if the frequency were 80 Hz lower? How much would the impedance be for a frequency 80 Hz higher? (Use the graph for these answers.)

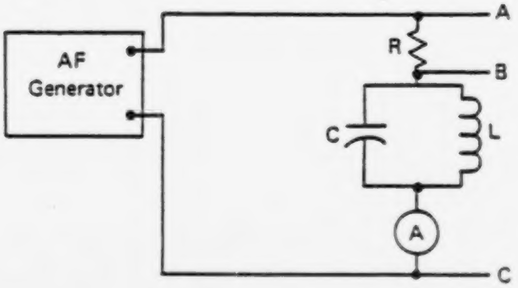
8. Does the graph confirm that impedance and current vary inversely with each other?

DETERMINE RESONANCE IN A PARALLEL RCL CIRCUIT

Equipment:

Audio frequency generator
Multimeter (electronic type)
Ammeter, 0-150μA
Capacitor, 0.001μF
Resistor, 10 KΩ, 1 watt
Inductor, 10 millihenry
Graph paper

Procedure:	Evaluation 3	2	1	N
1. Connect the circuit as shown in the following schematic.	___	___	___	___



2. Calculate the resonant frequency, F_R = __________ Hz.	___	___	___	___
3. Adjust the audio frequency generator to the frequency calculated in step 2.	___	___	___	___
4. Adjust the generator for maximum output.	___	___	___	___
5. Connect the voltmeter, which is set to the $5V_{AC}$ range, across the tank circuit (points B and C), making sure that the common leads of the generator and the voltmeter are both connected to point C.	___	___	___	___
6. Adjust the generator above and below the calculated frequency (step 2) until there is a maximum voltage reading and a minimum reading on the ammeter.	___	___	___	___
7. Record the frequency determined in step ? in the data table on this job sheet. This is the true F_R.	___	___	___	___
8. Adjust the generator for an output of one volt (points B to C).	___	___	___	___

9. Measure the voltage, V_C; enter V_C in the data table. _ _ _ _

FREQUENCY	V_C (tank)	I_T	X_L	X_C	I_L	I_C	Z (tank)
(F_R – 30KHz)							
(F_R – 20KHz)							
(F_R – 10KHz)							
F_R = ______							
(F_R + 10KHz)							
(F_R + 20KHz)							
(F_R + 30KHz)							

10. Measure and enter the total current, I_T, as indicated by the ammeter. _ _ _ _

11. Calculate the inductive reactance, X_L, at the resonant frequency and enter in the data table. _ _ _ _

12. Compute and enter the capacitive reactance, X_C. _ _ _ _

13. Calculate I_L and I_C and enter into the data table. _ _ _ _

14. Calculate the parallel tank circuit impedance, Z, and enter into the data table. _ _ _ _

15. Repeat steps 8-15 at 10KHz steps above and below the resonant frequency. Be sure to adjust the generator for one volt output with each change of frequency. _ _ _ _

16. Plot the tank circuit impedance (vertical axis) versus frequency points (horizontal axis) as calculated; enter in the data table. _ _ _ _

17. Connect the points to obtain a response curve. _ _ _ _

18. Return equipment and materials to storage area. _ _ _ _

Average of above evaluation* _ _ _ _

*This average is the student's final evaluation for competency B20: Test and evaluate filter performance.

Discuss the following.

1. Explain the difference between the true resonant frequency and the calculated resonant frequency.
2. Why is current at a minimum at the resonant frequency?
3. Does the tank circuit pass or block currents near the resonant frequency?

4. Is this a low Q or a high Q circuit? Explain.

5. Is the total impedance larger than the series resistor or approximately equal to it? Why?

6. What is the band width shown on the graph? Does this correspond with the band width formula?

MODULE: FUNDAMENTALS OF ELECTRONICS

UNIT IX: REACTIVE AND RESONANT CIRCUITS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Reactance is measured in units of _________ .

a. Henrys
b. Farads
c. Ohms
d. All of the above
e. None of the above

____ 2. Reactance opposes the flow of current _________ .

a. And eliminates phase shifts
b. But does not dissipate power
c. And is caused by resistors
d. All of the above
e. None of the above

____ 3. Inductors cause _________ .

a. No phase shift
b. Current to lead the voltage
c. Voltage to lead the current
d. 180° phase shifts
e. None of the above

____ 4. The quality of an inductor is _________ .

a. Related to the frequency applied to the circuit
b. Affected by the resistance of the inductor
c. Affected by the inductance of the inductor
d. All of the above
e. None of the above

____ 5. A 2mH coil at 25kHz will have an inductive reactance of _____ Ω.

a. 50
b. 12.5
c. 0.00318
d. 314
e. None of the above

____ 6. In a series RL circuit, the coil measures 6V, the resistor measures 8V and the applied AC voltage is _________ .

a. 10V
b. 14V
c. 2V
d. 48V
e. None of the above

____ 7. In a series RL circuit, $R = 30\Omega$, $X_L = 40\Omega$, $Z =$ _____ Ω.

a. 70
b. 50
c. 10
d. 1200
e. None of the above

____ 8. A pure inductor causes a phase shift of _____ degrees.

a. 90
b. 45
c. 360
d. 180
e. None of the above

____ 9. Z is the symbol for _________ .

a. Impedance
b. Inductance
c. Capacitance
d. Conductance
e. None of the above

____ 10. X_L is the symbol for _________ .

a. Impedance
b. Conductance
c. Resistance
d. Capacitive reactance
e. None of the above

____ 11. X_C is the symbol for _________ .

a. Impedance
b. Conductance
c. Resistance
d. Capacitive reactance
e. None of the above

____ 12. A capacitor causes _________ .

a. Voltage to lead the current
b. Current to lead the voltage
c. Resistance to increase
d. Resistance to decrease
e. None of the above

____ 13. A pure capacitor causes a phase shift of _______ degrees.

a. 360
b. 180
c. 90
d. 45
e. None of the above

___ 14. In a series RC circuit, $X_C = 15\Omega$, $R = 20\Omega$, $Z =$ _____ Ω.

a. 25
b. 35
c. 5
d. 300
e. None of the above

___ 15. A 10µF capacitor at 100Hz has a capacitive reactance of _____ Ω.

a. 0.00628
b. 0.001
c. 6.28
d. 159
e. None of the above

___ 16. In a series RC circuit, the capacitor measures 1.5V and the resistor measures 2V. The applied AC voltage is ________ .

a. 1.5V
b. 2V
c. 3.5V
d. 0.5V
e. None of the above

___ 17. Applied AC voltage in a series RC circuit is 10V. The capacitor has 3V across it, and the resistor has _____ V across it.

a. 7
b. 9.5
c. 13
d. 5
e. None of the above

___ 18. In a series RC circuit, the voltage across the capacitor is 15V. If the applied frequency doubles, the voltage will ________ .

a. Increase, but not double
b. Decrease, but not by half
c. Double
d. Decrease by half
e. Not change

___ 19. A purely capacitive circuit ________ .

a. Causes a 180° phase shift
b. Causes no phase shift
c. Dissipates maximum power
d. Dissipates no power
e. Will have a capacitive reactance unaffected by frequency

___ 20. A phasor diagram ________ .

a. Will show phase angle
b. Can be used for capacitive but not inductive circuits
c. Cannot be used for capacitors and inductors in series
d. Cannot be used with resistors that are a part of the circuit
e. All of the above

____ 21. A low-pass filter ________ .

a. Reduces the output of frequencies above a certain frequency
b. Passes signals only on the ground (low) line
c. Is made using inductors, but not capacitors
d. Is made using capacitors, but not inductors
e. None of the above

____ 22. A band-stop filter is ________ .

a. Also called a notch filter
b. Also called a pass filter
c. Made using inductors, but not capacitors
d. Also a pi filter
e. All of the above

____ 23. When the inductive and capacitive reactances are equal, ________ .

a. The circuit must be shut down
b. The circuit is safe to operate
c. Resonance occurs
d. This is the cut-off frequency
e. None of the above

____ 24. The resonant frequency of a 2mH coil and a 8μF capacitor is _____ .

a. 1600Hz
b. 1260Hz
c. 10kHz
d. 1.26MHz
e. 4kHz

____ 25. The resonant frequency of a band-pass filter is 4KHz. The Q of the circuit is 10. Therefore, the band width is ________ .

a. 4kHz
b. 400Hz
c. 40Hz
d. 4Hz
e. None of the above

Match terms with definitions.

____ 26. Designed to allow certain frequencies to be stopped or passed

____ 27. Contains both inductive and capacitive components. Its frequency causes the reactance of both components to be equal.

____ 28. The one-half power point (equal to the point where the voltage output drops to 70% of the input value) of a filter's output

____ 29. Passes lower frequencies and attenuates higher frequencies past its cut-off point

____ 30. Passes higher frequencies and attenuates lower frequencies past its cut-off point

____ 31. Passes only a specific range of frequencies; has a band-width rating

____ 32. Filter that rejects a specific range of frequencies; has a band-width rating. (also called a notch or reject filter and a trap)

____ 33. Range of frequencies centered around a resonant frequency passed or rejected by a filter

a. Band width

b. Band-pass filter

c. Band-stop filter

d. Cut-off frequency

e. Filter circuit

ab. High-pass filter

ac. Low-pass filter

ad. Pi filter

ae. Resonant circuit

ANSWERS TO UNIT TEST

1.	c	(B10)
2.	b	(B10)
3.	c	(B10)
4.	d	(B10)
5.	d	(B10)
6.	a	(B10)
7.	b	(B10)
8.	a	(B10)
9.	a	(B17)
10.	e	(B17)
11.	d	(B17)
12.	b	(B9)
13.	c	(B9)
14.	a	(B9)
15.	d	(B9)
16.	e	(B9)
17.	b	(B9)
18.	b	(B9)
19.	d	(B9)
20.	a	(B9)
21.	a	(B19)
22.	d	(B19)
23.	c	(B19)
24.	b	(B19)
25.	b	(B19)
26.	e	(B19)
27.	ae	(B9)
28.	d	(B19)
29.	ac	(B19)
30.	ab	(B19)
31.	b	(B19)
32.	c	(B19)
33.	a	(B19)